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RESEARCH REVIEW

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. . . give me commentators plain,

RESEARCH BRIEFS

Articles In This Issue

THE report of Dr. G. C. Drew and his co-workers Colquhoun and Long entitled, "Effect of Small Doses of Alcohol on a Skill Resembling Driving," has been recognized and acclaimed as an outstanding investigation. He reports that individual differences in response to alcohol appear to be related, at least in part, to personality characteristics. He found that while extraverts behaved and reacted as a group this could not hold true with introverts. Extraverts did not change either speed or control movement very much although they were less consistent in control movement, and showed large increases in error. The introverts changed speed considerably, but it was not possible to differentiate between those who slowed down and those who speeded up. Control movements also increased, but were relatively consistent. In all, Drew and his associates have considered a number of variables and established meaningful and significant relationships among them.

A substantial case is made in favor of the extended use of Drivotrainers by Dr. Herbert Stack in his report, "A Resume and Evaluation of Research on the Teaching Effectiveness of Simulated Driving and Conventional Driver Education Methods." Dr. Stack examines and summarizes the research of Bernoff at the University of Southern California, a study performed by Zaun *et al.* in the Los Angeles schools, and the investigation carried on by Rhum and Woodcock at Iowa State Teachers College. In each case the research indicated that favorable or comparable results could be had by simulated driving methods as contrasted with conventional behind-the-wheel instruction. Stack also presents some cost-per-student figures which should be of interest particularly to school administrators.

The techniques of statistical quality control were used by Blindauer and Michael in their report "An Analysis of High Accident Rates." The investigators made a study of 10 two-lane rural highways in Indiana on which there were high accident rates. Through selected analyses presented in the report the authors are able to show that statistical quality control is a useful tool in detecting accident-prone locations. They also indicate that assignable causes subject to elimination can be found rapidly and efficiently at many of the highway locations.

A. R. Lauer in his report, "Age and Sex In Relation to Accidents," undertook to answer the fundamental questions: Are reported accidents equally distributed among the population, age and number of licensees? Are accidents distributed equally among licensed drivers when mileage is held constant? What percentage of drivers is found in each age group? His findings coincide with that of others that the youthful driver contributes very heavily to the accident total.

The state of Oregon had considerable information about non-collision fatal accidents. Stewart, Hill and Warmoth made both a statistical and psychological analysis of these data. They present a number of tables and percentages that indicate how such accidents occur, where they occur, how many are fatal, etc. They also analyze such conditions as speed, passing, turning, drinking, sleep, mechanical failure, etc.

The report by Siebrecht, Schumacher, and Lauer, "Accident Characteristics of Drivers at Various Age Levels," considers age and sex in relation to accidents as Lauer has done in the previous article mentioned in this column. They go into more detail in establishing inter-correlations and validity co-efficients among such factors as age, year of car, experience, mileage, schooling, violations, etc. They further propose a new index of accident susceptibility that equates experience and mileage driven each year. This formula is given in the text of the study.

Research Grants

INVESTIGATORS are painfully aware of the fact that many well conceived projects and investigations die aborning due to lack of financial support. In many cases this support is available, but its whereabouts is unknown to the investigator. The National Institutes of Health represent probably the best single source of research aid. A special division has been in operation for some years devoted specifically to reviewing proposals for accident prevention. Investigators who are not already aware of their extensive program can obtain further information on it by writing to: Division of Research Grants, National Institutes of Health, Bethesda 14, Maryland. The packet and brochure the Division will forward contains full information on what kinds of research will be supported, how application is made, etc.

John J. Flaherty

. . . who with no deep researches vex the brain

—G. Crabbe (1754—1832)

THE AUTHORS

Herbert J. Stack

Dr. Herbert J. Stack is Program Associate of the Center for Safety Education and Consultant, Esso Safety Foundation. He was the first chairman of the Research Committee of the School and College Conference of the Council, and five years ago was honored by the Council for "25 years of conspicuous service to safety." He received the first Paul Hoffman Award in 1957, and in 1955 the Arthur Williams Award of the American Museum of Safety. Dr. Stack has been chairman or a member of the sponsoring committee for 35 individuals who have carried on research and completed requirements for the doctors degree at New York University. He holds a Ph.D. degree from Columbia University and an Ed.D. (hon) from the University of Massachusetts.

Harold L. Michael

Harold L. Michael, P. E., is a graduate Civil Engineer, having received the BSCE from Purdue University in 1950 and the MSCE degree from the same school in 1951. Prior to his entry into Purdue in 1947, he spent nearly four years in the Army, most of the time doing location survey work for field artillery battalions. In 1950 he joined the staff of the School of Civil Engineering at Purdue and currently is Assistant Director of the Joint Highway Research Project and Associate Professor of Highway Engineering at Purdue.

Mr. Michael has directed several metropolitan area traffic surveys for the State Highway Department of Indiana and is active in highway and traffic engineering extension work in the counties and cities of Indiana. He is the author of over thirty published technical papers.

Mr. Michael is active in several professional, civic, and religious groups. He is also a Lt. Colonel in the Army Reserve and Commanding Officer of a reserve unit in Lafayette. He is 39 years of age.

Elmer B. Siebrecht

Elmer B. Siebrecht is professor of psychology and education at Seattle Pacific College. He was graduated from St. Olaf College and the University of Minnesota. He received his Ph.D. from New York University for the development of the Siebrecht Attitude Scale, now widely used by driver education classes and transport companies.

He was co-author of the first college textbook for training teachers of safety education. He has written many school safety lesson outlines, spoken extensively before youth and adult groups on accident prevention, and with Dr. Lauer, has conducted research on the characteristics of drivers. He is a member of the National Safety Council Evaluation Committee of Safety Programs in Higher Education and last spring, participated in the Governor's Annual Safety Conference.

A. R. Lauer

A. R. Lauer is a professor of psychology at Iowa State College. He has received degrees from several colleges and universities: a master's in psychology from the University of Iowa in 1925; a M.S. in physiology from Iowa State College in 1928, and a Ph.D. from Ohio State University in 1929.

Lauer, together with his students and colleagues, has released about 200 theses, papers and articles, mostly concerned with the human element in safe driving. He has served as consultant on driving problems with the National Safety Council, the American Automobile Association, the Chrysler Corporation, the Ford Motor Co., the Adjutant General's Office of the Army and Air Force as well as with various transportation, insurance and utility concerns in the country.

Roger G. Stewart

Roger G. Stewart has been employed as a research phychologist in the Institute of Transportation and Traffic Engineering of the University of California and in the Department of Motor Vehicles of the State of Oregon.

In 1951, he received his Ph.D. degree in psychology from the University of Illinois, with major emphasis on experimental design of research studies, construction and validation of tests, and statistics. One of his chief interests lies in possible applications of these activities to problems in various fields of safety.

He is a member of the American Psychological Association. He is also certified as a psychologist under laws of the state of California.

Harlan H. Blindauer

Harlan H. Blindauer is a graduate of Montana State College of 1949 with a major in Civil Engineering. He also attended Purdue University and received the MSCE degree in 1958. Prior to attending Purdue, Mr. Blindauer was employed by the Montana Highway Department in highway construction and design. Currently he is a traffic engineer for Meissner Engineers, Inc., Chicago and is assigned to the Reno, Nevada office.

Mr. Blindauer is 33 years of age, married and has three children. He is a registered engineer in Indiana.

Charles Schumacher

Charles Schumacher obtained his B.S. from the University of Illinois in 1951, his M.S. from Iowa State College in 1953, and his Ph.D. in psychology from the University of Minnesota in 1959.

His research in traffic safety with Dr. Lauer has resulted in several joint publications. He has been elected to a number of honor societies, including Phi Beta Kappa, and has held All-state and National Science Foundation fellowships. He is currently the assistant director of research for the Association of American Medical Colleges, and is working in the area of selection and assessment of medical students.

EFFECT OF SMALL DOSES OF ALCOHOL ON A SKILL RESEMBLING DRIVING

by G. C. Drew, W. P. Colquhoun and Hazel A. Long

Since the drinking of alcohol in one form or another is so common a characteristic of the social life of man in a variety of cultures, it would seem important that as much as possible should be known both of its physiological effects and of its effects on behavior. In fact, at the present time, very little precise information is available, in spite of an extensive literature on the subject. This literature has been reviewed, more or less comprehensively, periodically since the early part of this century (Fisk, 1917; Darrow, 1929; Emerson, 1933; M.R.C. Alcohol Investigation Committee, 1938; Jellinek and McFarland, 1940; Drew, 1950).

The most striking feature to emerge from any such review is the marked lack of agreement between authors, amounting in many instances to direct contradiction of one another. This is especially true of the effects of smaller doses. Perhaps not surprisingly, doses of intoxicating strength have generally resulted in deterioration in efficiency in almost all aspects of behavior tested. For doses below this level, however, the picture is not clear.

Some authors have reported deterioration in performance however small the dose, some have failed to find any effects, while several have shown actual improvements following doses of the order of one single whiskey.

In part these discrepant findings reflect the unreliability of many of the results in this field, but in part they arise from the complexity of the effects of alcohol.

For moderate and intoxicating levels it has been established that the effect of alcohol is related to its concentration in the blood, and that the blood alcohol concentration obtained from a given ingested dose depends both on the body weight of the recipient and on the rate at which the alcohol is absorbed into the blood (Winton and Bayliss, 1948). The rate of absorption, in turn, has been found to be dependent on the amount, type, and dilution of alcohol, the contents of the stomach, and the drinking habits of the individual (Goldberg, 1951).

Previous reports further suggest that, apart from a slowly developed tolerance to alcohol from repeated exposure to it over a number of years, known as habituation, there is also a more rapid adaptation to each dose consumed, so that it has a greater effect when the blood alcohol level is rising than when it is falling (Mellanby, 1919; Miles, 1924; Goldberg, 1951; Eggleton, 1955).

The nature of the task used is also important. Goldberg (1943) has shown that some tasks are more readily impaired by a given dose than are others. Familiar tasks, too, deteriorate less than ones that are unfamiliar (Jellinek and McFarland, 1940). The method of measuring change in performance is often of great importance. The additional stimulation provided by a new task frequently enables the subject to compensate, for a short time, for conditions which have produced an overall reduction in his efficiency. For this reason, short interpolated tests may fail altogether to measure this deterioration and may show normal or even above normal efficiency (Drew, 1942). Reasonably long-lasting tests seem necessary unless the deficiency is a gross one. Welford (1951) has stressed the importance, for the analysis of skilled behavior, of measuring different aspects of performance, since relatively gross measures may obscure changes in the way in which different actions are integrated in the final performance.

The wide individual variations in performance in response to alcohol remaining when the above factors are taken into account have been attributed to temperamental differences, and especially to those differences related to extraversion-introversion.

Differences along this dimension have been noted in other contexts. Extraverts have been shown to be relatively less concerned with accuracy of performance (Himmelweit, 1946), to deteriorate more rapidly during continuous work (Broadbent, 1956; Eysenck, 1957a), and to be less consistent in performance (Venables, 1956). It has, furthermore, often been noticed, when giving depressant drugs to psychiatric patients, that a given dose has a greater effect on patients with hysterical disorders than on anxiety and depressive patients. A theory postulating a greater amount of cortical control for introverts and a greater susceptibility of extraverts to depressant drugs due to the reduction of cortical control was first put forward by McDougall (1929) and has recently been extended by Eysenck (1957b). Experimental confirmation of the greater susceptibility of extraverts to the depressant action of amylobarbitone sodium has been published by Shagass (1954, 1956).

The aims of this experiment were to investigate the effect of small doses of alcohol on a complex skill, resembling driving; to relate any changes found to the level of blood alcohol; to see whether individual differences in response to alcohol could be explained in terms of previous experience or of temperamental differences, when every effort had been made to minimize differences in blood alcohol level; and, finally, to investigate the accuracy with

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which blood alcohol level could be estimated by measuring the alcohol excreted in urine and in breath. This article is a preliminary report of the main results of the experiment which was carried out on behalf of the Road Users' Committee appointed jointly by the Medical Research Council and the Road Research Board (Department of Scientific and Industrial Research). Full details will be published later by the Medical Research Council.

Experimental Method

In deciding upon the task to be used, two considerations had to be borne in mind: that the task would need to be a continuous one of reasonably long duration, and that such a task runs the risk of becoming extremely boring for subjects. It was finally decided that an apparatus known as the "Miles motor driving trainer" provided the best compromise between a task, performance on which could be scored adequately, and one which had the motivating capacity of a real-life situation.

In this apparatus the subject sits in a dummy car, facing a translucent screen in a darkened room. Behind the screen is a "perspex" disk with a road scene painted on it. This road scene is projected, very much magnified, on the screen by a lamp on the perspex surface. As the driver operates the accelerator and steering-wheel to change his speed and direction of movement, the car appears to progress along the road. The effect is reasonably realistic, and the task bears some resemblance to driving in that non-drivers find the machine difficult to control without considerable practice, while experienced drivers have little difficulty with it. Though the central task is very similar to driving, it differs from it in being completely devoid of danger and emergencies. The track used was a continuous winding circuit, the equivalent of slightly over one mile in length. Its repetitive nature was not very apparent to the subjects, and had considerable advantages for scoring in presenting the same objective task to the subjects at all stages of the trial.

The main aspects of performance to be scored were accuracy of tracking, speed of driving, and the control movements of steering-wheel, accelerator, brake, clutch, and gear lever. Of the latter, only steering-wheel and accelerator pedal movements proved worth considering. Accuracy of tracking, measured in terms of deviations from a course parallel to the left-hand curb, and steering-wheel and accelerator pedal movements were recorded graphically, and simultaneously scored on counters, photographed once each lap. Separate recording was made of the number of collisions of the car with the side of the road; "hunting" movements of the steering-wheel too small to change the car's direction; gear changes; identification marks for lap completion and major corners; and a time mark.

The subjects were 40 volunteers from the staff of the Road Research Laboratory. Their ages ranged from 23 to 40 years, except for one subject aged 58. The mean age was 31 years. Five of the subjects were women. All were in good health and held a current driving license. The majority reported that they took alcohol only occasionally.

The alcohol was administered orally as analar grade absolute alcohol, diluted to a 20% solution and flavored to disguise the alcohol content. Haggard, Greenberg, and Cohen (1943) found that the toxic effect of alcohol varied considerably even within the same kind of spirit, owing, apparently, to the presence, in minute quantities, of substances related to the original distilling. They found that, after very careful distilling, absolute alcohol was less toxic than any of the other forms tried. As analar grade absolute alcohol was used in this experiment, it seems probable that the results reported here represent minimum effects for these quantities and concentrations. Equivalent amounts of alcohol taken as beer or spirits could be expected to have somewhat greater effects.

This investigation was concerned with blood alcohol concentrations of less than 100 mg. per 100 ml. of blood, since this is the figure recommended by the National Safety Council of America (1953) as the limit of "safe" and only "possibly under the influence." To achieve these concentrations, doses were given of 0.00 (placebo), 0.20, 0.35, 0.50, and 0.65 g. of alcohol per kg. of body weight. In terms of the concentrations used by Cohen, Dearnaley, and Hansel (1958) these doses represent approximately 18, 31, 44, and 57 ml. of absolute alcohol for a 154 pound (70-kg.) man. The largest dose is the approximate equivalent of three pints (1,700 ml.) of "average" beer or 5 fl. oz. (142 ml.) of whiskey for a 154 pound (70-kg.) man.

In view of the expected wide individual variations, and of the difficulty of defining a "correct" performance on such a task as this, it was decided to use each subject as his own control. That is, the effect of alcohol was measured as the degree of change in performance of each subject against his own performance without alcohol. To minimize practice effects, a latin square design was used, each square containing five subjects and five doses. This square was repeated eight times with different subjects. The women subjects were assigned to one square. Each subject was tested on the same day of the week for five consecutive weeks. Thus each subject received every dose.

Subjects were given preliminary practice to familiarize them with the task, and information was obtained on body weight, age, driving experience, and drinking habits. (They were asked not to drink on the evening before a trial.) On the morning of the trial the subject took a fat-free breakfast and 2 to 2½ hours later, at 10 a.m., the first urine sample was collected to provide a check on ketones and residual alcohol and to empty the bladder. (In a subsidiary experiment, urine samples were taken with a full bladder.) He was then given his drink and requested to finish it within 10 minutes. After a further 10 minutes he entered the apparatus and was instructed to drive as he normally would in a real car, and not to stop until told to do so, unless an emergency arose. The subject drove for 20 minutes and then had a 10-minute break, during which the blood, urine, and breath samples were collected. There followed three further 20-minute periods of driving, and 10-minute rest pauses during which samples were taken. Each experimental series lasted 2½ hours.

Approximately 0.5 ml. of blood was taken from the thumb on each sampling occasion, and the blood and urine samples were analyzed at the South-Western Forensic Science Laboratory, at Bristol, by the microanalytic modified Cavett method recommended by the B.M.A. Committee (Kent-Jones and Taylor, 1954). Samples taken on the alcohol-free days were usually discarded, but occasionally were used as a check on the analytic procedure. Readings from three instruments for the measurement of breath

alcohol were recorded at the time of blood sampling on a number of occasions. The breath analysis instruments used were the "Alcometer" (Greenberg and Keator, 1941), the "Drunkometer" (Harger, Lamb, and Hulpieu, 1938), and the "Breathalyser" (Borkenstein).

The subjects were given a battery of personality tests, from which only the measures of extraversion are considered in this paper. Tests included the Minnesota Multiphasic Personality Inventory, the Maudsley Personality Inventory, and the Bernreuter Personality Inventory.

ALCOHOL CONCENTRATION

Blood Analysis.—The means and standard deviations of each dose, in mg. per 100 ml. of blood, are given in Table 1. It will be observed that peak concentrations for the four doses were roughly 20, 40, 60, and 80 mg. per 100 ml. of blood. The doses used, therefore, have been effective in producing concentrations normally regarded as low or "safe." It will be seen from the standard deviations that there is relatively little overlap between the concentrations

TABLE I—*Mean Blood Alcohol Levels, and Standard Deviations, Following Four Doses of Ingested Alcohol*

Dose	Time After Drinking in Minutes							
	30		60		90		120	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1. (0.20 g./kg.)	23	10	19	9	13	8	6	5
2. (0.35 g./kg.)	36	15	37	10	30	9	20	9
3. (0.50 g./kg.)	58	14	59	11	51	12	39	10
4. (0.65 g./kg.)	74	19	77	12	71	14	62	13

following different doses, implying that the technique of adjusting the absolute quantity of alcohol given to total body weight produces reasonably consistent blood alcohol values. The change in the mean blood alcohol values for each dose through time is shown in Fig. 1. Following each dose, blood alcohol rises steeply to a maximum, reached somewhere between 30 and 60 minutes after drinking, and then falls off in an approximately linear way.

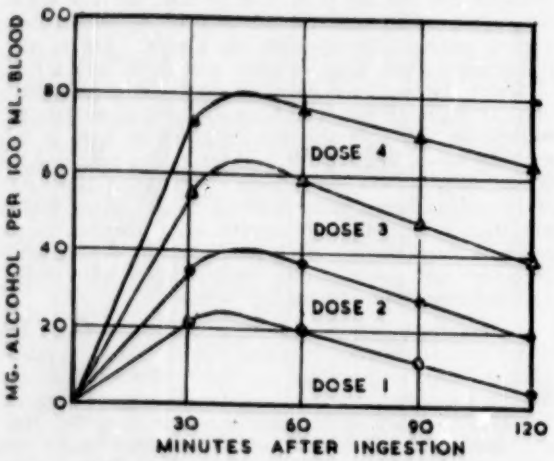

FIG. 1.—Relation between the level of alcohol in the blood and time after ingestion, for four levels of alcohol. Each point is mean of 40 subjects.

There is a tendency for the peak concentration to occur slightly later as the dose increases. That following the largest dose gives a mean time of nine minutes later than that for the smallest. For some subjects, measurements were taken up to six hours after drinking. Dose 1 fell to near zero concentration by the end of two hours, dose 2 at about four hours, dose 3 at rather over five hours, and at six hours the mean concentration following dose 4 was still 20 mg. per 100 ml. Once the peak was passed blood alcohol levels fell, on average, by approximately 10 mg. per 100 ml. per hour.

Urine Analysis—Full details of the urine and breath analysis will be given in the main report. The concentration of alcohol in urine built up more slowly, reaching a peak concentration between 20 and 25 minutes later than that in the blood. After the peak was passed the fall-off paralleled that in the blood, the value at any given time being proportionately higher. The overall ratio of urine to blood alcohol was 1.252:1. When the samples were taken with the bladder full, values were slightly more variable, but did not differ significantly from those taken after the bladder had been emptied. Correlating the urine alcohol level with that in the blood 30 minutes earlier, to make an approximate correction for the time lag, gives a product-moment correlation of $r = +0.92$.

Breath Analysis.—Of the instruments used to analyse alcohol in expired breath, the Breathalyser proved most satisfactory. It proved highly reliable and gave values corresponding closely to the blood alcohol values, having a constant error of + 2 mg. per 100 ml. Some difficulties were experienced with the other instruments used. In 95 per cent of the comparisons the Breathalyser values lay within ± 21 mg. per 100 ml. of the blood alcohol readings, the Drunkometer within ± 22 to 26 mg. per 100 ml., depending on the operating technique used, and the Alcometer within ± 34 mg. per 100 ml.

PERFORMANCE CHANGES

The aspects of performance measured concerned the accuracy of tracking, the speed at which the task was taken, and the operation of the controls.

The accuracy measures consisted, firstly, of tracking error (the amount of deviation across the road surface from a track parallel to the left-hand curb) and curb-bumpings (the more serious error of colliding with the side of the road). Secondly, two detailed accuracy measures were obtained—positioning of the car relative to the left-hand side (this was measured on a sample of 10 subjects for no-alcohol and dose 4), and consistency in car positioning at a corner in the circuit (measured, for 35 subjects, as the range of differences in negotiating the same corner on six successive occasions in the second driving period under each dose condition).

Speed was recorded as the number of seconds taken to complete one lap. The total amount of steering-wheel movement made will be the only aspect of control movements considered here.

All scores were expressed as a summed score per lap, and were then averaged over five minutes. The five-minute averages were then summed over 20 minutes. They were subjected to a variety of statistical treatments, including

analysis of variance. Regression lines and coefficients of correlation are used here.

The results are presented in terms of group effects, followed by some discussion of individual differences in response to alcohol and their relationship to other personal characteristics. A table of the mean effects of alcohol for each scoring category is given in the Appendix.

A. Group Effects

Practice effects varied in the different performance measures. Tracking error showed very little change with practice, but there was a progressive increase in speed of driving throughout the experiment. Time per lap and tracking error were negatively correlated ($r = -0.39$), but correction of error scores for increased speed makes little difference to the overall picture. Steering-wheel movement shows a pronounced practice effect in a progressive and marked reduction in the amount of movement throughout the experiment.

Effect of Alcohol on Accuracy

Accuracy of steering, in a complex task of this kind, decreases progressively as blood alcohol increases, even with the low concentrations used in this experiment. Furthermore, there is, from the group effects, no evidence of a threshold. Instead, there is a measurable increase in mean error as soon as there is a measurable quantity of alcohol in the blood. The relation between accuracy, expressed as tracking error, and blood alcohol is shown in Fig. 2. This shows the regression of error on blood alcohol. The regression is highly significant ($p<0.001$). This is confirmed by an analysis of variance, which shows a relation of error and blood alcohol significant at better than the 0.01 level of probability. The mean increase in error for the 80 mg. per 100 ml. concentration compared with no-alcohol performance is about 16 per cent.

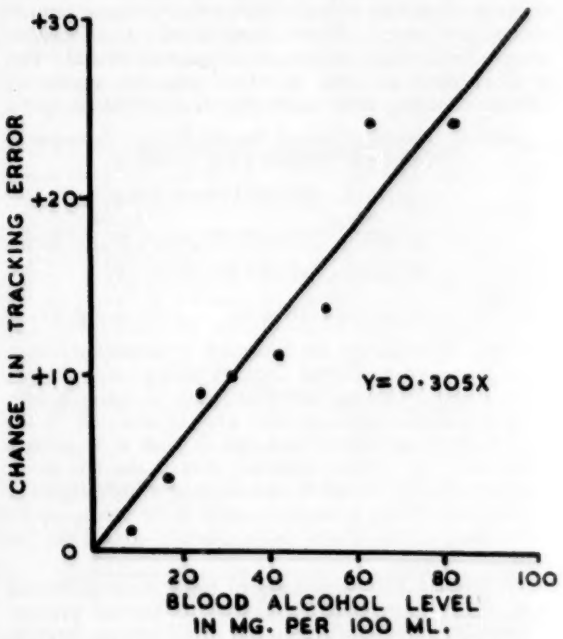

FIG. 2.—Regression of tracking error on blood alcohol level. Each point is mean of 80 paired values.

It has been noted above that blood alcohol concentration shows a characteristic change with time after drinking, showing, first, a steep rise to a maximum value, followed by a slow return to normal. Tracking error shows a very similar pattern with time after drinking. The close correspondence of the rise and fall through time of blood alcohol and tracking error is shown in Fig. 3. In this figure, tracking error scores are expressed as the mean score for each driving period. Blood alcohol concentrations have therefore been expressed in the same way. The rise and fall of urine alcohol, expressed similarly, have been included. The figure for urine alcohol has been reduced by one-fifth (in view of the ratio of 1.252:1) to enable it to be presented on the same scale. Although only the largest dose has been plotted, the data for the other doses follow the same pattern.

It can be seen that urine alcohol reaches a maximum about 20 minutes later than blood alcohol. The error curve looks as though its peak would occur somewhere between the two. The calculation of lag correlations confirms this. Maximum correlations are obtained when error scores are correlated with blood values some 10 minutes earlier, and with urine values some 10 minutes later. From this it would appear that maximum error slightly lags in time behind the maximum blood alcohol and slightly precedes maximum urine alcohol.

Product-moment correlation of the rise and fall of blood alcohol and the rise and fall of error is positive and significant. The mean correlation of the four paired values, calculated separately for each individual, is $r = +0.271$, with p lying between 0.01 and 0.02. The size of this correlation, though significant, seems small. It will be seen from Fig. 3 that there is a time lag between the two variables with an inverted relationship in periods 2-3. This, and the clustering of points in the second, third, and fourth driving periods, probably have reduced the size of the correlation. When blood alcohol values at five-minute intervals, obtained by interpolation from the individual curves, are correlated with the five-minute error scores, allowing a much smaller lag than the 20-minute scores, the correlation rises to $r = +0.89$. Because the test ends before blood alcohol has dropped very markedly, it is not possible from these scores to say whether error scores recover more quickly than blood alcohol levels, though inspection of Fig. 3 shows that the slope of error scores in the last half hour is steeper than for blood alcohol. The frequency of curb bumping rises steeply to a maximum, for each dose, with blood alcohol, and falls almost equally steeply after the maximum has been passed.

In an attempt to interpret the increased error with increased blood alcohol, records were sampled for mean position on the road surface, amount of swing about this position, and consistency of behavior on corners. Significant differences were found. Without alcohol, subjects tended to drive on the left-hand side of the road, to remain on that side for relatively long periods—that is, with relatively little "wobble"—and rapidly to correct swings to the

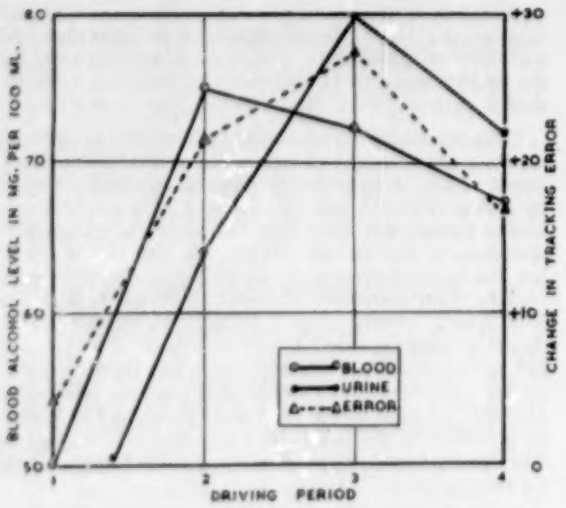

FIG. 3.—Rise and fall of blood alcohol, error score, and urine alcohol with time after drinking. (Urine alcohol levels reduced by one-fifth.) Each point is mean of 40 subjects.

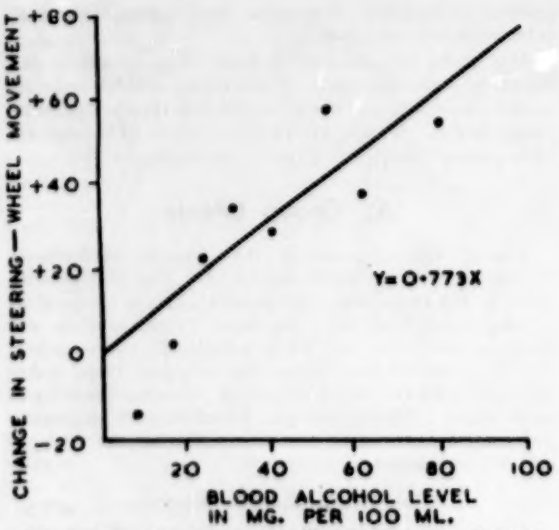

FIG. 4.—Regression of steering-wheel movement on blood alcohol level. Each point is mean of 80 paired values.

right by moving back to the left once more. The effect of alcohol appears to be to produce a shift of the mean driving line from the left towards the crown of the road ($p<0.01$). With increasing dosage there is an increasing swing or "wobble" about this new, more central position ($p<0.01$), together with a tendency to tolerate swings to the right but rapidly to correct swings to the left ($p<0.01$). There was, furthermore, greater variability in the positioning of the car in negotiating a corner ($p<0.01$).

Effect of Alcohol on Speed

In this experiment there were no clear-cut group effects on speed of driving. Mean driving speeds are insignificantly different for all doses. Variability in speed around a mean shows a tendency to rise and fall through time with blood alcohol rise and fall, but this again is not significant. It is possible that the large effect of practice on speed is camouflaging any alcohol effect for the group. Changes in speed of driving after alcohol were found to be closely related to personality characteristics. These are discussed below.

Effect of Alcohol on Steering-wheel Movement

Like error, steering-wheel movement increases progressively as blood alcohol increases. The regression of amount of change of steering-wheel movement on blood alcohol is shown in Fig. 4. This regression is linear and is highly significant ($p<0.001$). There is also a decrease in the consistency of steering-wheel movement after alcohol ($p<0.01$). The decrease in consistency appears to be due to a greater variability in the timing of responses to a corner.

As might be expected, the amount of steering-wheel movement is related to the amount of tracking error made. The relationship is U-shaped, such that there is an optimum amount of movement for controlling the car, both less and more movement resulting in increased error. Following alcohol there is an increasing tendency to make either too little or too much movement in negotiating a particular corner, though the predominant effect is to make too much.

B. Individual Differences in Response to Alcohol

Although the latin square design used makes comparison of the performances of individuals difficult, certain features nevertheless emerge. There is undoubtedly a considerable range of individual variation in response to alcohol. This is summarized in Table II, which gives the number of subjects changing their score after alcohol by varying amounts. The changes are expressed as percentage change from their own no-alcohol score. Tracking error shows a wide scatter. Though the distribution is fairly heavily skewed towards increased error after alcohol, 10 of the 40 subjects show reduced error, one as much as 50 per cent reduction. This subject, however, showed also one of the largest reductions in speed, and achieved a high degree of accuracy by driving extremely slowly. Time scores, on the other hand, are distributed fairly normally around the "no change" position.

TABLE II—*Number of Subjects Showing Different Percentage Change in Scores After Alcohol (Dose 4)*

Measure	Percentage Change of Score										
	Decrease					Increase					
	−50	−40	−30	−20	−10	+10	+20	+30	+40	+50	+60	+70
Error	1	0	2	2	5	10	12	4	2	2	—	—
Steering-wheel movement	—	—	—	3	5	12	15	5	3	—	—	1
Time	—	—	4	5	11	13	5	2	—	—	—	—

An attempt has been made to relate these individual differences in response to alcohol to various personal characteristics. No relationship was found between response to alcohol and differences in initial level of skill, previous driving experience, age, sex, or drinking habits. The sub-

jects varied widely in their initial level of skill and in previous driving experience, so the lack of relationship between these variables and alcohol effect may be stated with some confidence. The range of drinking habits, however, was small, so that the comparison was between the few individuals who drank once or twice a week and those who drank very rarely. The range was therefore too small to draw conclusions on the lack of relationship.

Scores obtained, for 35 subjects, on the extraversion scale of the Maudsley Personality Inventory were well distributed. The mean was 10.24 (sigma 4.53) as compared with the standard norm of 10.94 (sigma 4.74). Performance scores were compared for a group of subjects scoring high in extraversion and a group scoring low. Fig. 5 shows the mean differences in tracking performance between the resulting seven extraverts and nine introverts. The extravert group made more error ($p<0.05$), were less consistent in car positioning ($p<0.05$), and showed a bigger increase in error during each period of driving ($p<0.01$). The effect of alcohol on error was greater for the extravert group ($p<0.05$), the extraverts having an average increase of 23 per cent and the introverts of 6 per cent.

The extraverts responded to alcohol in a similar manner, but the introverts showed more varied responses. For example, the extraverts all increased their tracking error after alcohol, whereas two of the introverts made less error. This is especially clearly shown in the effect of alcohol on speed of driving. The extraverts showed very little change of speed after alcohol, but the introverts changed considerably. The nearer the introvert end of the scale they were, the more speed changed. They subdivided, however, into two distinct groups, one of which speeded up very considerably, and the other slowed down. It has not so far been possible to relate this to any personal characteristics. Fig. 6 shows the regression of change of speed on extraversion—introversion as measured by the Bernreuter Neurotic Inventory. This regression is linear and is significant at the 5 per cent level. Comparing those scoring more than 50 on the Bernreuter with those scoring less than this in terms of whether they change speed by more or less than 8 units gives a X^2 significant at better than 0.01. It would appear that personality characteristics —at least those of the extravert-introvert dimension—are related to the effects of alcohol.

DISCUSSION

It is now generally agreed that a relationship exists between the concentration of alcohol in the blood and the appearance of clinical signs of intoxication. The definition of intoxication based on clinical evidence is, however, a variable one. Liljestrand (1940) gives evidence of a considerable variation in diagnoses made by different clinicians on people who all had blood alcohol concentrations between 100 and 150 mg. per 100 ml. Moreover, the range of blood alcohol concentrations at which people are judged intoxicated is very wide. Goldberg (1951) has shown that the level at which 50 per cent of people are judged clinically to be intoxicated varies with the legal definition in different countries. In America it has been defined by the National Safety Council as 150 mg. per 100 ml., in Sweden it is 100-120 mg. per 100 ml., and in Denmark and Norway 80 mg. per 100 ml.

The level of alcohol in the blood at which people are diagnosed clinically to be intoxicated, besides being variable, tends to be high in comparison with the concentrations used here. This is not surprising, since an estimate of impaired behavior is made in the absence of any criterion of normal behavior for that individual, so that the impairment must be obvious before it is detected, and since it is known that people can compensate for their reduced efficiency over the short periods of time during which they are examined. It does not follow, however, that, because no impairment is found in clinical tests, more complex skills, like driving, will also be unaffected.

The present study shows that performance begins to

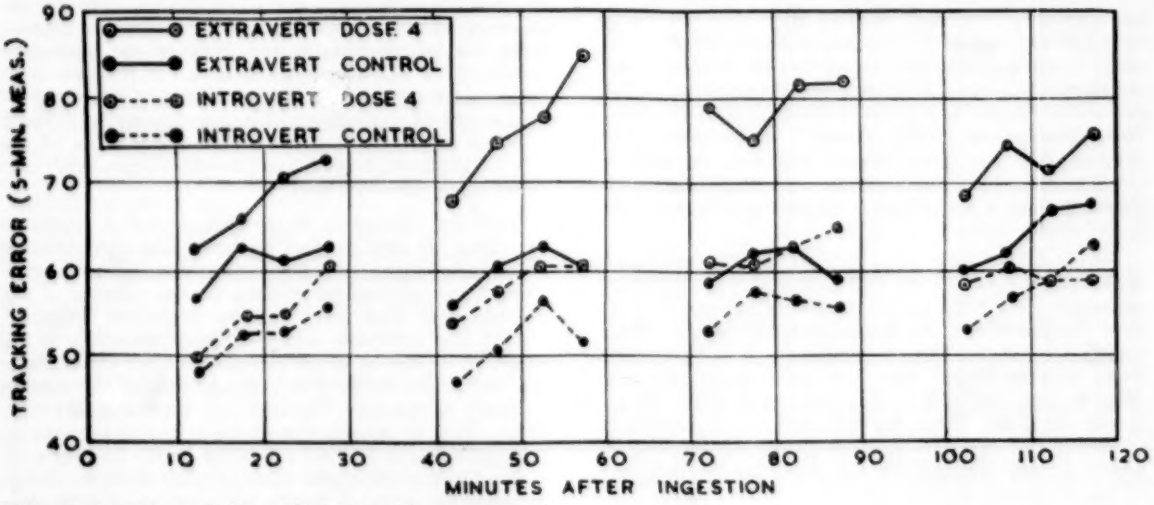

FIG. 5.—Comparison of the tracking error of extraverts and introverts under no alcohol and dose 4 conditions. Extraverts $n = 7$; introverts $n = 9$.

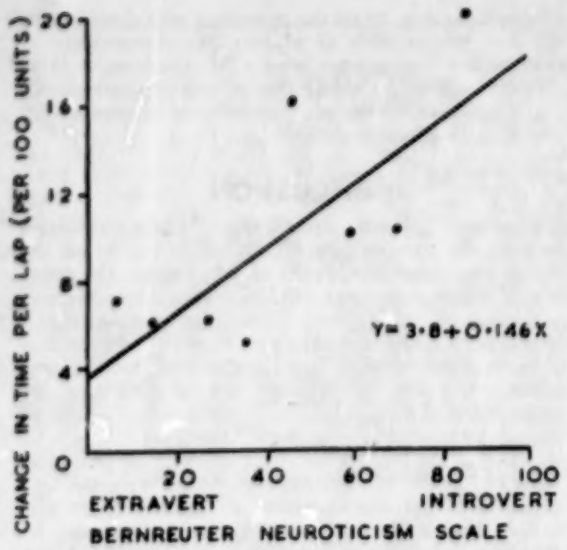

FIG. 6.—Regression of change of speed after alcohol on extravert-introvert score. Each point plotted is mean of five subjects.

deteriorate with very low blood alcohol concentrations, certainly of the order of 20-30 mg. per 100 ml., and that the deterioration is progressive and linearly related to blood alcohol level. There is, in this study, no evidence of a threshold effect.

The impairment of performance was shown most clearly in the operation of the controls. As the aim of the task was primarily to track, it is perhaps not surprising that in attempting to retain a level of accuracy the operation of the steering-wheel should be most affected. Efficiency in using the steering-wheel is indicated by the amount of tracking error which results. With practice the amount of steering-wheel movement made goes down without a reduction in the accuracy of tracking, whereas after alcohol tracking error increases despite an increase in steering-wheel movement. This suggests that timing of the steering-wheel movements was upset. The decrease in consistency of the movements required to negotiate a corner supports this view. The importance of timing of control movements in a complex skill has been stressed previously by Bartlett (1943), and adverse conditions such as fatigue have been shown to have a marked effect on timing (Drew, 1942; Russell Davis, 1948).

The work of Cohen *et al.* (1958) is interesting additional evidence. While the task used in this present study reasonably reflects the tracking aspect of driving, it is almost completely free of hazard and risk-taking. These authors have shown that an amount of alcohol not much larger than the biggest dose used in this experiment produced a significant increase in the hazards in which drivers became involved. From the two studies it is reasonable to assume that not only will drivers become involved in greater hazards with this amount of alcohol but they will be less efficient in dealing with them.

It is suggested, furthermore, that the results reported here show that the level of alcohol in the blood is a good indicator of the extent of impairment of performance. It may be pointed out that the blood alcohol levels reported by Cohen *et al.* (1958) seem surprisingly low. Assuming their drivers to weigh rather more than 154 pounds (70 kg.), on average, their two doses correspond fairly closely to the smallest and biggest used here. Their blood samples, however, would appear to have been taken almost two hours after subjects began to drink. If this is so, the blood alcohol levels correspond very closely to those found here. They report a concentration of 4 mg. and 58 mg. per 100 ml. for the two doses. At two hours comparable figures in this experiment were 6 mg. and 62 mg. per 100 ml.

While this in no way affects the conclusions reached by these authors about the effect of such doses on performance, it does affect their discussion about "safe" levels of blood alcohol. At the time of the tests the blood alcohol levels in their drivers would almost certainly be at least 10-20 mg. per 100 ml. higher than those reported. Even so, their experiments, and these, suggest a marked impairment of performance on such tasks with blood alcohol levels of 60 to 80 mg. per 100 ml.

In view of the known difficulty of clinical estimates of impairment in such situations, and of the individual's capacity, if he is capable of realizing that he is under test, to compensate temporarily for loss of efficiency, estimation of blood alcohol level would seem the most direct way of assessing impairment. Estimation of the alcohol excreted in urine and in breath allows a close approximation to blood alcohol. In these experiments, urine alcohol agreed very closely with blood alcohol. Breath analysis, which has enormous administrative advantages over both blood and urine analysis, can, from these results, given a suitable instrument, also give a very close approximation.

It would seem fairly clear, from these results, that the efficiency with which a task like driving is performed is likely to decrease progressively as blood alcohol rises. At some point the loss of efficiency is likely to be large enough to constitute a danger in a practical driving situation. As this experiment has been carried out in a laboratory, necessarily free of the hazards and many of the motivating features of a real-life situation, it is not possible, from these results, to say at what level of blood alcohol the increased risk of accident would become unacceptable. Some evidence on this is available from the experience of the U.S.A., Denmark, Norway, and Sweden, where rather different cut-off levels are used.

Individual differences in response to alcohol appear to be related, at least in part, to personality characteristics, especially those of extraversion-introversion. Eysenck (1953) has collected the evidence for the existence of this dimension of personality and has postulated (Eysenck, 1957a) that extraverts would be more susceptible to the effects of depressant drugs like alcohol. The extraverts in this experiment behaved as a group, and tend to confirm Eysenck's hypothesis. The introverts do not behave as a group. It is of interest that all the scales used agreed on the extravert end but did not agree on the introverts. It is possible that the almost bimodal effect noted on change of speed for introverts reflects the intrusion of some other personality characteristic not tested in this experiment. The test which showed this bimodal effect most clearly was the

Bernreuter, which uses a more "neurotic" criterion of introversion than the Maudsley.

In this experiment extraverts appear not to be bothered by the extra stress imposed by alcohol. They drive at much the same speed as before, make very little additional corrective movements, but make much greater error, are less consistent, and deteriorate more rapidly during 20-minute driving periods. Introverts, on the other hand, appear to be striving to compensate for the alcohol effect, and to be anxious to demonstrate their efficiency. They over-react to the situation, make more corrective movements of the steering-wheel, and change their speed markedly. Some slow right down, presumably in an attempt to achieve accuracy, though they do not necessarily do so, while others appear to be attempting to demonstrate how quickly they can drive, again not always with a proportionate loss of efficiency.

SUMMARY

An experiment has been carried out to investigate the effects of small doses of alcohol on a complex skill.

Four alcohol doses and a placebo dose were used. The peak blood alcohol concentrations from the doses were approximately 20, 40, 60, and 80 mg./100 ml. of blood.

Urine and breath analyses were compared with direct blood analysis. Urine alcohol peaked later and higher than blood, but breath alcohol followed blood alcohol in time. The ratio of urine alcohol to blood alcohol was 1.252:1.

Three kinds of breath-testing apparatus were used. Best results were obtained from the "breathalyser." The others either showed high constant errors or were unreliable. The results from the breathalyser were good enough to warrant its consideration from a practical point of view.

Mean error showed an increase with increase in blood alcohol, amounting to about 16 per cent deterioration with a blood alcohol concentration of some 80 mg./100 ml. Part at least of the increase in error is to be explained by a significant tendency for subjects to move towards the right-hand side of the road after alcohol and also by less consistent positioning. Error scores and control movement scores also showed a variation in time, rising and falling in a way similar to that of blood alcohol.

Mean speed showed no significant change, but marked individual differences in speed after alcohol were found.

Control movements, as measured by steering-wheel movement, showed significant increases and a significant reduction in consistency.

Age, sex, previous driving experience, and previous drinking habits, within the limits available, showed no relation to individual differences in response to alcohol.

Personality ratings, especially those relating to extraversion-introversion, showed a definite relation to behavior changes. Extraverts did not change either speed or control movements very much, though they were less consistent in control movements, but showed large increases in error. Introverts changed speeds considerably, though it is not possible to differentiate between those who slowed down and those who speeded up. Control movements also increased, but were relatively consistent. Error may or may not increase, but the mean error score was significantly less than that for extraverts.

APPENDIX

Average Scores For Various Aspects of the Tracking Task, After Each Alcohol Dose

Performance Variable	Dose 0	Dose 1	Dose 2	Dose 3	Dose 4
Tracking error	227	230	235	246	246
Curb bumpings	209	255	350	260	359
Inconsistency in tracking	4.82	5.08	5.63	5.78	5.53
Time per lap	403	390	386	393	398
Steering-wheel movement	674	673	690	708	764
Inconsistency in strong-wheel movement	3.61	3.51	3.61	4.03	4.15

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A Resume and Evaluation of Research on the Teaching Effectiveness of Simulated Driving Experiences and Conventional Driver Education Methods

by Herbert J. Stack

In recent years, in spite of the general increase in the number of schools teaching driver education, many school districts have moved to discontinue the practice driving phase of driver education. Several explanations have been given for this, but, undoubtedly, one of the most important is the cost of the conventional methods of teaching practice driving. While there is substantial evidence as to the value of driver education, school districts nevertheless are attempting to reduce school budgets.

In the last decade there have been various attempts to lower the cost of teaching practice driving. One of these, the off-street multiple car plan originating at Lane Tech in Chicago, adopted in Detroit, and recently included in over twenty-five cities in Michigan, is an outstanding illustration. This program does reduce costs materially. Another plan, involving the Aetna Drivotrainer, provides for the training of from one to 25 students at a time through an inter-related use of model cars, a series of 20 motion pictures, and a master console housing the projector, scoring and recording apparatus. This training program provides for learning through simulated driving experiences. Leslie Silvernale, Assistant Director of the Highway Traffic Safety Center at Michigan State University, reports that students at the Center are not only given Drivotrainer instruction, but this is followed by experience in an off-street practice area. Both of these methods do increase the number of students that can be trained, thereby decreasing costs.

There are now over 70 Drivotrainer installations in various communities in the country. The number is increasing steadily and as a result, during the past summer, several colleges offered credit courses for training teachers who will be in charge of new installations.

The questions naturally arise, "What about the quality of the learning that takes place with the Drivotrainer? While more students can be given instruction, how do they compare in knowledge, skills, and attitudes with those completing conventional practice driving? What has research shown regarding the value of such simulated training?"

Two important statements of policy regarding simulators were made in 1958. The first of these came out of the National Conference on Driver Education held at Purdue University:

> "In recognition of simulators, the value of which has been established by research, simulated driving experience can be used in lieu of half of the recommended ratio of four to one. Decision for approval of any simulator should be the responsibility of the individual State Department of Education."

A second is from the Driver Education Section of the National Safety Council:

> "The National Safety Council supports and encourages the use of laboratory equipment to simulate behind-the-wheel driver experience in high school driver education courses. Also, the Council encourages continued research as to the manner in which such devices can be most effectively used in the teaching of driver education."

It is always difficult in limited space to make a satisfactory summary of research of this kind, and in this instance the three studies that have been reviewed cover over 350 pages. It should be borne in mind that each of these studies is comparing the value of two systems or programs, one which includes 16 periods on the Drivotrainer, plus three hours of practice driving and six of observation time; the other, the conventional, entailing six hours of practice driving and 12 of observation time.

1. AN EXPERIMENTAL STUDY OF THE TEACHING EFFICIENCY OF THE AETNA DRIVOTRAINER[1]

This research was conducted by Louis I. Bernoff in partial fulfillment of the Ed.D. degree at the University of Southern California.

Purpose of the Study

A. Do driver-attitude test scores of students trained with the Drivotrainer differ significantly from the scores of students trained in a minimum conventional course?

B. Do driver-knowledge test scores of students trained with the Drivotrainer differ significantly from the scores of students trained in a minimum conventional course?

C. Do driver-skill test scores of students trained with

This report reviews three research studies on the value of the Aetna Drivotrainer.

[1] *An Experimental Study of the Teaching Efficiency of an Electro-mechanical Device and Conventional Driver Training Methods.*— Louis I. Bernoff, University of Southern California, 241 pages.

the Drivotrainer differ significantly from the scores of students trained in a minimum conventional course?

Experimental Design

Selection of Groups

A. An experimental group (Drivotrainer instruction) of 120 students was selected from one school and a control group (conventional instruction) of 120 from two other schools.

B. The two groups of students were chosen so as to be comparable on the basis of age, previous training in driver education, and previous driving experience. The percentage of girls and boys in both groups was approximately the same.

Pre-tests and Post-tests

Before training began and immediately on completion, all students were tested with the following instruments: *The Siebrecht Attitude Scale, Knowledge Test for Man and the Motor Car, Knowledge Test for Sportsmanlike Driving,* a *Final Road Test* and a *Drivotrainer Final Test.*

Instruction

A. The experimental group was given 16 hours in the Drivotrainer, supplemented by three hours behind the wheel and six hours of observation time. (total, 25 hours)

B. The control group was given six hours behind the wheel and 12 hours of observation in a dual-control car.

C. Two instructors taught with the Drivotrainer and two with the conventional course.

Statistical Procedures

A. The groups were compared by testing the significance of mean differences (using critical ratios) in driving attitude, knowledge and Drivotrainer final criteria.

B. The significance of the difference of medians was employed to compare the results of the final road test.

C. Significance of correlations between chronological age, intelligence, and previous driving experience, respectively, and the final road test, was tested by Chi Square.

Major Findings (Summarized)

Before Training

The dual control group had a higher mean driving attitude score than the Drivotrainer group (significant only at the 10 per cent level).

There was no significant difference in knowledge scores between the two groups.

After Training

No significant differences existed in knowledge scores between the two groups.

No significant differences in driving attitude scores existed between the two groups.

Both groups showed a significant positive mean change (.01 level) between pre- and post-instruction knowledge test scores.

The Drivotrainer group had a significant mean change in attitude (.01 level), while the control groups had no significant change.

There was no significant difference between the two groups in median road test scores.

Conclusions (Quoted)

1. The Drivotrainer is a device which can be used successfully to train students as adequately, or possibly better, than they are now being trained by conventional means.

2. Training with the Drivotrainer offers a wider and richer variety of experiences than conventional means for the improvement of driving attitude.

3. Because of extended and more intensive training offered with the Drivotrainer, students' driving knowledge tends to increase more than with conventional training.

4. There is evidence to suggest that the Drivotrainer can be used more advantageously with homogenous groupings according to age, sex, and mental ability.

5. The Drivotrainer definitely offers a given staff the opportunity to train approximately thirty per cent more students in a school year than can now be trained by conventional means. This could result in tremendous savings to the taxpayer.

6. In view of the fact that this investigation was successfully attempted in a public high school with a normal school program, there appears to be no reason why the Drivotrainer could not be installed in any public high school to function in the regular school curriculum.

II. RESEARCH IN THE LOS ANGELES SCHOOLS (an abstract)[2]

This study was carried on under the direction of Cecil G. Zaun, Supervisor of Safety, Dr. Alfred S. Sewerenz and Howard A. Bowman of the Evaluation and Research Section of the Los Angeles Schools.

Purpose of the Study

A. To compare the results of 16 class periods of instruction on the Aetna Drivotrainer, plus three periods of practice driving and six of observation, with the results of six periods of practice driving and 12 of observation time in the conventional method of training. Changes in knowledge, attitudes and skills were used as criteria.

B. To determine the number of students that could be given instruction by both methods and the relative per-pupil costs.

Experimental Design

The design used in this preliminary study was the same reported by Dr. Bernoff. The difference was largely in the number of students in control and experimental groups.

Findings

The reported results of this study were much the same as those reported by Dr. Bernoff.

1. The control group showed a significant improvement in all test scores except on the Siebrecht Attitude Scale.

2. The experimental group showed a greater improvement in skills and attitudes.

3. The two groups showed no significant differences in the final knowledge testing.

4. Students in the experimental group, trained partly on the Drivotrainer, appeared to be just as competent drivers as those in the control group given instruction in conventional practice driving.

Observations on Costs

Based on a program of 15 class hours in the Aetna Drivotrainer and three in a car, 480 students can be trained in one year with an eight-place installation at a savings of $6.17 per student. This includes the amortized costs and

[2] *An Evaluation of the Teaching Effectiveness of the Aetna Drivotrainer.* Los Angeles Public Schools.

maintenance of the Drivotrainer. With a fifteen-place installation, the savings would be $11.65 per student.

III. THE IOWA STATE TEACHERS COLLEGE RESEARCH[3]

This was carried on under the direction of Dr. Gordon J. Rhum and Bertram L. Woodcock and summarized by Dr. Tom A. Lamke, all members of the faculty of Iowa State Teachers College.

Purpose of the Study

To compare the results of four (and later three) hours of driving instruction in a dual control car, plus instruction with the Drivotrainer, with the results of a conventional program involving six hours of instruction in a dual control car.

Experimental Design

Selection of Groups

A. Six classes totalling 79 students were selected for the experimental group and 86 for the control group.

B. The first two classes in both groups were matched using Otis I.Q. tests; *Iowa Tests of Educational Development;* composite scores; grade point averages in academic subjects; rating of personal traits; previous driving experience; and family ownership of a car.

C. The other four classes were selected as a random sample from the population available and were randomly assigned to the experimental and control group. The t-test for the significance of the difference in criterion means for independent small samples is appropriate for this design.

D. The criterion used was the Final Driver's Test, published by Iowa State Teachers College, except in group 1, where the *Iowa Driver's License Examination* was used.

Conclusions

The outcomes of the experimentation are reported as establishing that, with the given criterion, results produced using the Drivotrainer and three hours of dual-control-car instruction were at least as satisfactory as the results produced by the standard method of instruction involving six hours of dual-control-car instruction.

Simple computations show that one instructor can provide driving instruction for about a third again as many students using a 10-place Drivotrainer installation (15 hours in the Drivotrainer, three in a dual-control-car) as he can with six hours of dual-control-car instruction.

SUMMARY AND DISCUSSION

Nearly everyone who has completed a research project of the experimental type can later think of ways in which it could have been improved. For illustration, in both the Bernoff and Los Angeles studies it would have been better if instructors could have been rotated, particularly since attitudes constituted one of the criteria. (In the Iowa study, the same instructor taught both the experimental and control group.) Many of the following observations will deal with the Bernoff study, since it is the most elaborate in design; others obviously have general application.

Comparison of Driving Performance

The relative driving performance of the experimental and control groups was investigated in all three studies. While different criteria of performance were used, the writer feels that they were satisfactory in each case. In all three studies no significant difference was found between the post-instruction performance of experimental and control groups. Students trained on the Drivotrainer were just as skillful as those taught by conventional methods. This, the writer feels, is an important conclusion.

Instructors have recognized for a long time that a good part of the first periods is spent acquiring neuro-muscular skills of coordination—manipulating gears, steering, making turns, and the like. Over ten years ago, studies at Lane Technical High School in Chicago showed the value of practice on dummy cars before students were assigned to practice driving on an off-street area. Such skills can be acquired on classroom training apparatus.

Improvements in Knowledge

It was also of interest to find in both the Bernoff and Los Angeles studies that while there was a significant increase in knowledge in the two groups, both reported that the difference between the two groups in the pre-tests and in the post-tests was not significant. Pre-test comparability is essential to a tight design.

Of course, several of the films used in the Drivotrainer program, such as those dealing with "driving emergencies," might well provide experiences which would be difficult to include in practice driving. Moreover, the 16 periods on the Drivotrainer plus three of practice driving would appear to give more experience—and thereby affect knowledge more—than six periods of practice driving. But this must be viewed as a subjective impression of the writer.

Changes in Attitudes

For some time it has been felt that improvement of attitudes was primarily the function of classroom instruction. There has been little research reported on the value of practice driving in improving attitudes. Bernoff, however, reported that while the control group had shown higher scores in the pre-test, after training the difference between the two groups was not significant (five per cent level of confidence). The Siebrecht Attitude Scale was used in determining these findings, which therefore depend on the Scale's validity. It is of interest to note that, using this criterion, the control group showed no significant improvement in attitudes.

CONCLUSIONS

There is good evidence from the studies that the use of the Drivotrainer for 16 periods, plus three periods of practice driving and six of observation time, results in just as much learning, measured in terms of skill, knowledge, and attitudes, as six periods of conventional practice driving and 12 of observation time.

Such a program, furthermore, is noted as being considerably lower in cost than the conventional program, the difference depending largely on the number of cars in the installation.

The statements of policy by the National Conference on Driver Education and the National Safety Council that appear earlier in this paper warrant careful consideration. It is important for driver educators not to be so wedded to current plans that they are not ready to try out other programs that may produce better results, at substantially lower costs.

From a research point of view there is, of course, a great need for experimentation and evaluation to determine desirable ratios of general classroom instruction and behind-the-wheel instruction for maximum student achievement in driving knowledge, skills, and in attitudes affecting safety.

[3] *The Effectiveness of the Aetna Drivotrainer in Driver Education.* Iowa State Teachers College.

AN ANALYSIS OF HIGH ACCIDENT RATES

Statistical quality control furnishes some significant results

by H. H. Blindauer and H. L. Michael

INTRODUCTION

With the advent of the automobile as a mode of transportation late in the nineteenth century, a new phenomenon, the motor vehicle accident, appeared on the American scene. While the motor vehicle was in its early stages of development, the problem was not serious. However, as the volume of cars on the highways increased, the number of accidents increased also; and the problem began to assume greater and greater proportions. Today many million accidents occur each year, resulting in nearly 40,000 deaths and costing the American economy more than four billion dollars.

Three elements contribute to automobile accidents; the driver, the vehicle, and the highway. Quite obviously, the highway engineer does not have complete control over the first two elements since driver characteristics are the result of individual characteristics and may be subject to change by education and enforcement, and vehicle characteristics are primarily controlled by the automotive industry and public desire. The highways, however, are the responsibility of the members of the highway engineering profession, and it is also the responsibility of this group to make them as safe as possible for all drivers. In view of the ever increasing number of accidents on American highways, the highway engineer has many opportunities to contribute to safer highways.

The year 1956, with the passage of the Interstate Highway Act, produced a concerted effort to build safety into highways; but the 41,000 miles comprising the Interstate Highway System is only slightly more than one per cent of all roads in the United States. Even after this vast system of superhighways is built, a large percentage of the remaining highways will be below acceptable standards. Because, in all probability, there will never be enough money to reconstruct all roads to modern standards; it is up to the highway engineer to make existing highways as safe as possible under prevailing conditions.

However, present highways cannot be made safer in the most efficient manner until more information concerning accidents has been compiled and analyzed. At present, most states keep very complete files of accident reports, but very little has been done in utilizing these reports in accident analyses of sections of highway. This is at least partially due to the fact that accident reports are often inaccurate and incomplete as to location, type of accident, and prevailing conditions at the time of the accident.

The role that highway elements play in contributing to accidents is, at the present time, relatively unknown. Many investigations have been performed in the past attempting to correlate accident rate with such factors as the number of intersections and driveways, horizontal and vertical curvature, road and shoulder width, traffic volume, capacity, structures, number of lanes, grades, and commercial and residential development along the highways.

In general, however, the results of these investigations have been inconclusive, and, in some instances, contradictory. Some results of accident studies have indicated, however, that correlation of accidents with some elements of the highway at specific locations is very good and that a study of accident records can indicate this correlation. As a result, this study of high-accident highways in Indiana was begun.

In this study, all sections of highway investigated were two-lane highways in rural areas. Two-lane rural highways were selected because a large percentage of the highways in Indiana have only two lanes and probably will remain two-lane highways for many years to come and, as a result, the greatest need for research is on this type of facility. Rural highways were selected for this first study because of the relative homogeneity of conditions affecting accidents on these roads.

Selection of Test Roads

In the selection of test roads, three criteria were utilized: (1) each of the test road sections should be of sufficient length to present several different subsection accident rates; (2) the overall accident rate on each test road section should be above the average accident rate in Indiana; and (3) the test roads should be located throughout the state in order to present a variety of conditions.

This paper is a report on a Purdue University Joint Highway Research Project.

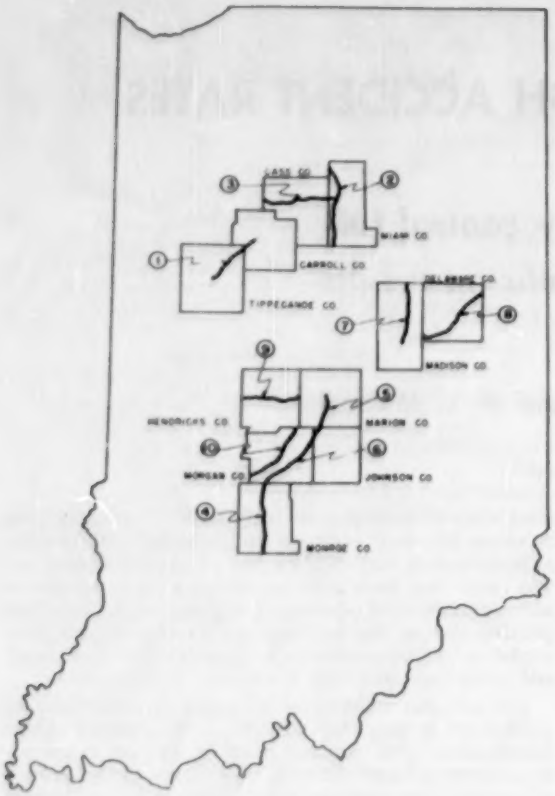

Figure 1

Ten rural sections were selected and are shown on a map of Indiana in Figure 1. They are, with the listing number corresponding to the number on the figure, as follows:

(1) State Road 25—Lafayette to Delphi
(2) U. S. Highway 31—Miami County
(3) U. S. Highway 24—Burnettsville to Peru
(4) State Road 37—Monroe County
(5) State Road 37—Indianapolis to Johnson-Morgan County Line
(6) State Road 37—Morgan County
(7) State Road 9—Anderson to Madison-Grant County Line
(8) State Road 67—Delaware County
(9) U. S. Highway 36—Hendricks County
(10) State Road 67—Morgan County

Each section was then subdivided into subsections of convenient length, usually one mile. In general, the subsections were numbered by direction from the major town or city on the section with the terminal points of each subsection half-way between integer miles from the city limits. This division was used because most accident reports gave the location of an accident as an integer number of miles from the city limits of the major town or city within the county in which the accident occurred.

Collection of Data

It was next necessary to locate as accurately as possible the various major highway elements which might be a factor in accidents, such as private and commercial driveways, intersections, structures, and railroad crossings. This information was used in the data analysis, and it also helped to locate many accidents quite closely since a majority of accident reports not only gave the mileage to the nearest city but also gave a distance from some feature such as an intersection or a structure in the immediate vicinity. A Streetor-Amet Travel Time and Distance Recorder was used in this location phase of the research.

After the highway features on all ten test sections were located and recorded in the proper subsections, the recording of accidents was begun. When this study was initiated, it was planned that the accidents would be recorded according to the type of friction which caused each accident; ie., intersectional, marginal, medial, or internal stream friction. However, it was found that the accident descriptions on most of the reports were vague and inconsistent, and the data resulting from such a procedure was very doubtful as to its accuracy.

An approach was used, therefore, which gave reasonably accurate and useable results. The accidents were classified according to the highway features at which they occurred. The classifications used in this study were (1) accidents occurring at intersection; (2) accidents occurring at structures; (3) accidents occurring at railroad crossings; and (4) other accidents. Structures included all major and minor bridges but not culverts.

All accidents which occurred in the two-year period from January 1, 1956, to December 31, 1957, were recorded according to this classification and, as accurately as possible, by subsection.

Traffic volumes for the ten test sections were obtained from the 1957 Traffic Flow Map of Indiana published by the State Highway Department of Indiana.

ANALYSIS OF DATA

Since the purpose of this study was to determine causes and possible methods for reducing accident rates on specific sections of highway, some method had to be found which would emphasize those subsections having accidents due to assignable causes. It was first planned to utilize correlation and regression in locating assignable causes; but, as the study progressed, another method of analysis was used which presented much better results. That method was statistical quality control.

Statistical quality control has been used for many years in American industry to gauge the performance of men and machines. Control charts with appropriate control limits give a good indication of variation due to random error alone and variation due to assignable causes. Therefore, it seemed logical that if quality control could gauge the performance of machines, it might also be used to gauge the performance of highways. The idea of using quality control in accident analyses is not entirely new as

several applications of this technique in recent years have been reported in the literature and with promising results.

In specific terms, the quality control type of accident analysis is as follows: A section of highway is divided into subsections, and the accidents on each subsection are compiled. The accidents are converted to some standard unit of measure and plotted on a control chart. The appropriate upper control limits are computed and also plotted, and those subsections which are out of control are investigated further for assignable causes. If this method is applied to several sections of highway, as it was in this study, it remains substantially the same with one exception; the sections are tested first to ascertain whether or not they are in control. All sections in control are tested using the overall average value, and any section out of control is tested separately using its own average value.

It is important to note that even though a very large majority of the subsections will be in control, this does not necessarily indicate that there are not present on these segments assignable causes which contribute to accidents. This is especially true for this study because only high-accident highways were considered for analysis.

When the above procedure was applied to this study, one problem immediately arose. What would be a logical standard unit of measure for the four types of accidents? For accidents occurring at intersections, structures, and railroad crossings, the answer was relatively simple. Since all of these types occurred at single points, they could be converted to an element of risk:

$$\text{Element of Risk} = \frac{\text{Number of Accidents of a Class for a Period of Time}}{\text{Total Traffic Volume on Road for the Same Period}}$$

Because the subsections used in this study were generally one mile or less in length, no more than one structure, intersection, or railroad crossing usually occurred in each subsection. In the very few subsections where more than one of any of these features occurred, each intersection, structure or railroad crossing was analyzed separately if the subsection was out of control.

An additional refinement to the element of risk for intersections and railroad crossings could be made by including in some manner the traffic volumes on cross roads for intersection analysis and the number of trains per day for railroad crossing analysis. These refinements were not incorporated in this study because of the non-availability of traffic volumes on cross roads and of comprehensive information on train movements.

For other accidents, the problem was somewhat different. Since these included accidents due to horizontal and vertical curvature, private and commercial driveways, insufficient pavement and shoulder width, congestion, and other factors, it was reasoned that, in general, they might be more or less uniformly distributed throughout each subsection. Therefore, the question of subsection length arose because, in all probability, accident occurrence on a subsection two miles in length would be greater than on a subsection one-half mile long if similar conditions were present on both subsections. To account for this, it was decided to use vehicle miles traveled on the subsections rather than vehicles in the denominator of the element of risk equation:

$$\text{Element of Risk} = \frac{\text{Number of Accidents of a Class for a Period of Time}}{\text{Total Vehicle Miles Traveled on Road for the Same Period}}$$

With standard units of measure for accidents determined, only one problem remained, that of finding a standard expression for the control limits of the various sections and subsections. In order to find the solution, it was necessary to refer again to quality control as used in industry.

When dealing with fraction defectives, a mean and standard deviation can be computed for the binomial distribution; and, although the distribution may be quite skewed, there will be, by chance causes alone, very few points outside the band between the mean minus three standard deviations and the mean plus three standard deviations. Hence, having set such limits, the statistician has a band of normal variability for the statistical measure of interest.

When applied to this study, the statistical expressions are as follows:

$$p_i = \frac{a_i}{n_i}$$

$$\bar{p} = \frac{a_i}{n_i}$$

$$s_i = \frac{\bar{p}}{n_i}$$

$$CL_i = \bar{p} + 3\, s_i$$

Where p_i = the element of risk on any subsection

$\bar{p}$ = the average element of risk on any section or series of sections

a_i = the number of accidents on any subsection

n_i = the number of vehicles or vehicle-miles on any subsection, the unit of measure depending on the type of accident being analyzed

s_i = the estimate of the standard deviation of any subsection

CL_i = the control limit for p_i on any subsection

Elements of risk were computed for each section and each subsection for accidents at intersections, at structures, at railroad crossings or at other locations. The analysis of the ten sections revealed that only one of the sections—

SR 37 from Indianapolis to the Johnson-Morgan County Line for intersection accidents—was out of control. This indicates that there is a strong possibility that accidents are occurring at intersections on this section of highway for some reason other than chance alone. A detailed study of all intersections of this entire road section would be desirable.

All other sections of highway and types of accident were found to be in control—in other words the numbers and types of accidents occurring on these sections of several miles in length might be due to chance alone and no assignable cause of accidents is indicated for an entire section.

The subsections of each section of highway were next analyzed for accidents at intersections, at structures, at rail crossings, and at other locations by the control chart tech-

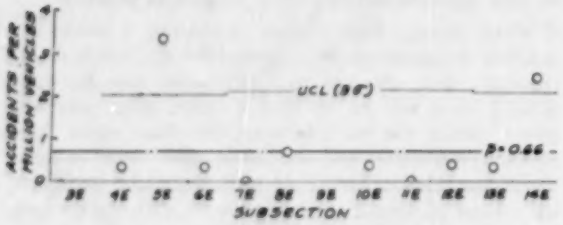

Figure 2

nique (see Figure 2). The p value used in each case was the average element of risk for a class of accidents for all subsections of all test sections of highway, except that intersection accidents on out-of-control SR 37 just discussed were excluded. The control limits were then computed for each subsection and the results plotted on control charts for each section. The number of accidents was also plotted for each subsection. If the plotted point was below the upper control limit the subsection was in control. If the point was above the control limit, the subsection was out of control, or in other words there was a good probability that accidents were occurring in this subsection because of some assignable cause in the subsection. Such analysis revealed the following:

a) For accidents at intersections, 15 out of 188 subsections were out of control.

b) For accidents at structures, 6 out of 73 subsections were out of control.

c) For accidents at rail crossings, 1 out of 10 subsections was out of control.

d) For other accidents, 11 out of 207 subsections were out of control.

Search for Assignable Causes

After the out-of-control subsections were located by visual inspection of the control charts, it was necessary to reappraise the accidents on those subsections in an attempt to find assignable causes.

Again utilizing the accident reports for the years 1956 and 1957, collision diagrams were made for all intersections, structures, railroad crossings, and other locations of accidents within the out-of-control subsections.

From this final accident analysis, it was possible at a number of the locations to isolate features which caused or contributed to the occurrence of accidents. All out-of-control locations were also investigated in the field to find what conditions existed which were hazardous to motorists, and what remedial measures could be taken to reduce the accidents at those locations.

The search for assignable causes was very profitable. Assignable causes of accidents were found on 86 per cent of the out-of-control subsections, and no assignable cause could be found on only 14 per cent of the out-of-control subsections. Five examples are given in the following paragraphs to illustrate the effectiveness of this analysis technique in the location of assignable causes for accidents.

Figure 2 shows a portion of the control chart for accidents at intersections for SR 25 from Lafayette to Delphi. Two subsections are out of control—subsections 5E and 14E.

The intersection in Subsection 5E is the intersection of SR 25 and SR 225 about 5 miles northeast of Lafayette. Figure 3 is a collision diagram of all accidents at that intersection. Note that of ten accidents at this location, eight were rear end collisions with vehicles waiting on SR 25 to turn left on to SR 225. An inspection of the intersection revealed the fact that this intersection is not readily visible to traffic approaching the waiting vehicles because of alignment and grades near this intersection. The recommendation at this site was to install a "Side

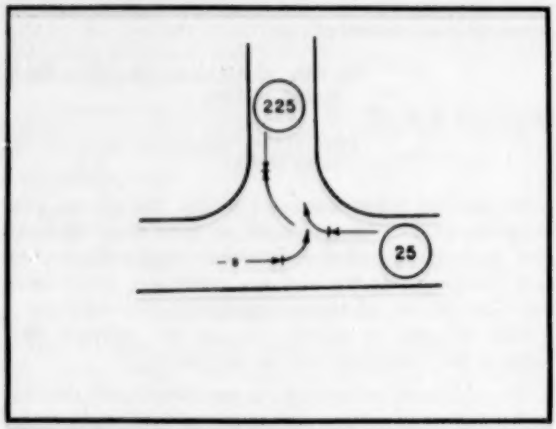

Figure 3

Road" sign west of the intersection and to construct a refuge lane for vehicles wishing to turn left.

The intersection in the other out-of-control subsection (14E) is the intersection of SR 25 and US 421 at the southeast edge of Delphi. The collision diagram for this intersection is shown in Figure 4.

The flat angle of divergence which must be used by vehicles wishing to turn left from SR 25 to US 421 resulted in head-on collisions (two accidents) with vehicles coming from Delphi and rear-end collisions with vehicles traveling east on SR 25 (five accidents). The recom-

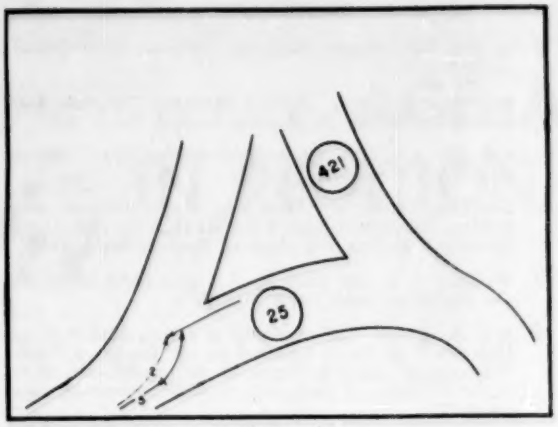

Figure 4

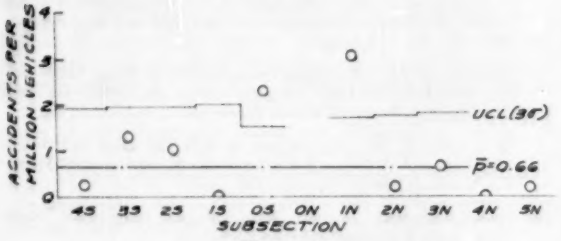

Figure 5

mendation here was to construct a channelized T intersection which would include a refuge lane for the left turning vehicles.

A portion of the control chart for intersections for SR 67 in Morgan County is shown in Figure 5. Subsection N is one of two which is out-of-control. The intersection in this subsection is the intersection of SR 67 and SR 39 north of Martinsville.

The collision diagram of this intersection is shown in Figure 6. Eight of the ten accidents are similar, and

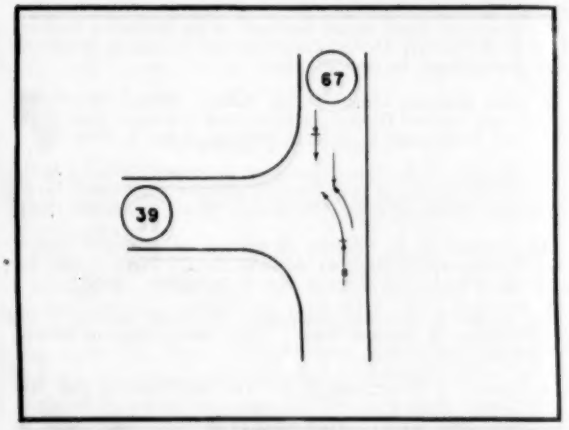

Figure 6

occurred because of lack of visibility south of this intersection coupled with a very inconspicuous warning sign of the intersection. The recommendation was made to install an oversize "Side Road" sign south of the intersection and to construct a refuge lane for the left turning vehicles.

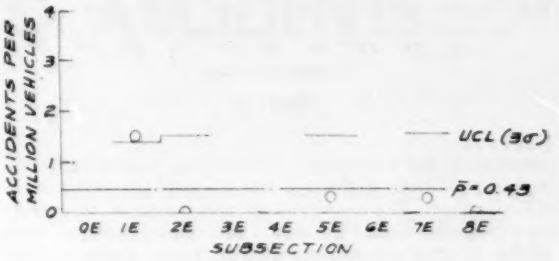

Figure 7

The control chart for accidents at structures on SR 25, Lafayette to Delphi, is shown in Figure 7. One subsection (1E) is out-of-control. The structure is the new bridge over Wildcat Creek just north of Lafayette. It is of excellent width and observation would lead one to conclude that elements at this structure are very safe.

The collision diagram (Figure 8) indicates, however, that the nearness of the side road at one end of the bridge is resulting in rear-end collisions between vehicles turning left and others travelling south from Lafayette. Six one car accidents have also occurred at the bridge which involved vehicles travelling north, and closer investigation revealed that these latter accidents occurred when the tem-

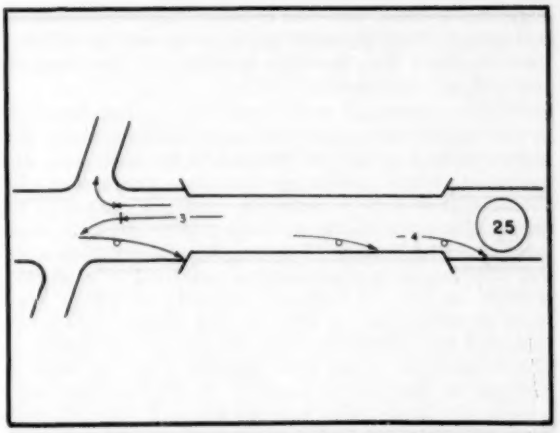

Figure 8

perature was very near the freezing point. Recommendations included quick deicing maintenance on the bridge and warning signs of the side road.

A portion of the control chart for accidents at structures on US 24 from the White-Cass County Line to Peru is shown in Figure 9. Subsection 5E is out-of-control. The

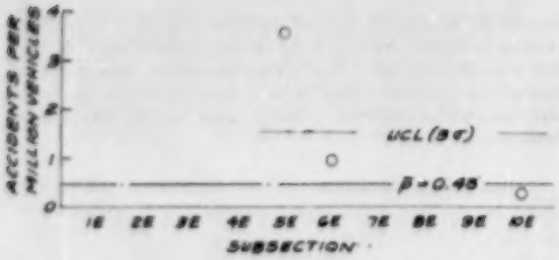

Figure 9

structure in this subsection is the overpass separating US 24 and the Wabash Railroad. All 11 accidents occurred at the structure. The extremely narrow width of this structure coupled with bad horizontal and vertical curvature west of the structure are undoubtedly the causes. Reconstruction and relocation are the solutions here, but a speed zoning of US 24 in this vicinity was recommended for the present.

These are only a few examples of the results found in this study, but they do show that here is a statistical tool that is useful in locating accident-prone highway locations. They also indicate that assignable causes subject to elimination can be found rapidly and efficiently at many of the high accident locations.

Editor's Note

One of the authors of the preceding paper experienced an unusual incident related to the subject material of the paper and because of its interest it is included here.

A few days after presenting the paper at the 45th Annual Purdue Road School, one of the authors in the company of friends who had read the newspaper account of the paper was travelling to a city some distance from Lafayette, Indiana. The road on which they were travelling was one of those included in the study and several discussions about the hazardous locations on that highway occurred as they approached them.

As they approached a T intersection on Test Section 3 at which a very large number of accidents had occurred, the author made a remark of that fact to his colleagues. He further explained as they approached the intersection (the intersection of U.S. 31 and U.S. 24 at the west edge of Peru) how most of the accidents resulted between westbound vehicles on U.S. 31 turning left (to go south without stopping as they are directed) in front of eastbound vehicles on U.S. 24 (who are supposed to stop). They were travelling east on U.S. 24 and another vehicle approached the intersection from the east as they halted at the intersection. There was sufficient time for them to continue so they moved forward. As they left the intersection the author, who was looking back, saw the exact type of collision he had just described as a vehicle which had been following his own stopped at the intersection and then pulled in front of the westbound vehicle turning left to go south on U.S. 31. Fortunately the damage was slight.

A recommendation to correct this situation at this intersection was made to the State Highway Department and they are now drafting plans for the channelization and signalization required.

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AGE AND SEX IN RELATION TO ACCIDENTS

by A. R. Lauer

It was with the hope that some of these confusing issues might be cleared up that a 5-year study of age and sex has been undertaken at Iowa State College. The specific hypothesis set up as a basis of the present paper may be stated as follows: Reported accidents are distributed evenly throughout the driving population according to density of population, age, and number of licensees. A corollary hypothesis to be tested may be formulated as: Accidents are distributed evenly throughout the driving population on the basis of miles driven by each age group.

In addition, answers to the following questions are sought through various studies in progress: Are age trends in accident involvement, as secured from the accident files, consistent? Are accident reports in a given community an index to its fatality record? Is reporting uniformly carried out within a state and is it in any way associated with density of population? If the hypotheses set up are confirmed, what would be the most fruitful immediate approach to the motor-vehicle accident problem? If the hypotheses are rejected, where should we start to improve drivers?

It is obvious that, as a rule, shot-gun methods in education, engineering, or any other field of endeavor will be less effective than systematically planned and organized effort. The least that can be left to chance the better. It is assumed that accident reporting is impartially carried out with respect to sex and age groups within a given municipality, state or territory.

Method and Procedure

This study was undertaken in cooperation with the Department of Public Safety in Iowa, the data presented being from Iowa.

The method is of statistical and analytical nature and consists of drawing a systematic sampling of the drivers' license files in the state by examining and tabulating the data from every 200th card of the 1,300,000 licenses in the state. The cards are jacketed and contain information on all accidents, violations, and revocations made by the licensee since the drivers license law became effective in Iowa in 1933. Overload and nonmoving violations were not included, since they may not be the fault of the driver. It is the information of the writer that standing violations, such as parking tickets, are not entered in the records.

It suffices to say that the reporting system developed gradually, as in other states, and that reporting became more efficient as the patrol was increased and more attention was given to accident reporting by the local traffic courts and enforcement agencies. Consequently, the increased number of accidents reported does not necessarily serve as a true index of the total number of accidents occurring within a given period. This is shown by the sharp jump in 1948 when the financial-responsibility law went into effect. The number of reported accidents increased over three-fold.

After the list of 7,692 cases comprising the first sample of licenses used in this part of the study was drawn and prepared, a double, specially printed postcard was sent to each person requesting further information regarding the mileage driven annually by day and night. Other questions were asked about the way the person learned to drive, mileage on the car, age of car, model, ownership of car, and certain other related data. Only items referring to age, licensure, mileage, violations, and accidents will be reported here as taken from the state records. A second sample of 7,275 cases was drawn by taking every 250th card.

The data were assembled and punched on IBM cards for analysis by age groups, sex, and location and according to mileage driven annually. Accidents, violations, age, and personal data were taken from state files. The data were recorded by years of age to the nearest birthday, but only accidents and violations for the years 1948 and 1949 were considered in this study due to the lack of consistency prior to that date.

Results

It was first considered necessary to make an estimate of the number of potential drivers in a state the size of Iowa for each age group. This is shown in Table 1 and

The study was made possible through a grant from the Allstate Insurance Company and set up as the Allstate Foundation for Driving Research. All possible cooperation was given by the Department of Public Safety for Iowa.

was based upon census figures. It was further considered that the percentage change would not likely be significant as it may well represent certain parameters of the driving population for the various age levels.

A proper analysis of any problem is essential to an adequate solution. It seems that the problems of age and sex in relation to automobile and traffic accidents have been sometimes confused, due partly to the emotionality of writers on the subject.

Age and sex both need be considered, since differences between the sexes are noted at various age levels. It is unintelligible to speak of the problems concerning one without a proper clarification of the limits of the other.

In order to treat an ailment, the doctor must find the origin of it or the part affected. Medication for eczema is not likely to help one with arthritis. Too often we try to reduce accidents by shot-gun remedies. Until the causes and those responsible for most of the trouble are singled out the proper methods of accident reduction cannot be determined.

The purpose of this paper is primarily to untangle some of the faulty conclusions that have been widely discussed about youthful drivers, women drivers, and older drivers. It is also hoped that it may stimulate greater care in coding the exact ages of drivers by the state licensing bureaus. Unfortunately, huge sums of money are spent annually in hoarding accident records and making compilations of simple tables, but little if any really scientific analysis is made of them. It is time that this practice is changed. We need to digest the results of accident reporting so that leads may be obtained which will be useful in educational, legislative, and enforcement circles to aid in accident reduction.

A very important aspect of the problem is the uneven grouping of ages for comparative purposes. The terminologies used are even confusing. Writers of popular articles on "teen-age" drivers sometimes construe the term to include every age up to 25 years. It was reported in one state that 3 per cent of the licensed drivers were 20 and below and were having half the fatal accidents from 12 midnight until 6 a.m. A recheck of the files showed that over 9 per cent of their licensees were 20 and below, since 20-year olds were classified with "teen-agers."

A great deal of the benefit of accident files are now being lost. Much unnecessary labor needs to be done at times in order to secure the information that could very easily be gotten if we had the breakdown by years in the files. Here are a few things which would improve the usefulness of accident files.

1. Besides the age of the driver, the date when he received his first license should be recorded.

2. How he learned to drive an automobile based on several categories which could be indicated in small print.

3. The approximate mileage one has driven up to the time he receives a license.

4. Number of years he has driven when licensed.

5. Number of cars he has driven to become familiar with them.

There are several questions which arise in considering this general problem and there is danger of one being misunderstood. These may be stated as follows:

1. What percentage of all persons licensed are women and what percentage are men?

2. What percentage of all persons licensed are women of a given age?

3. What percentage of all persons licensed are men of a given age?

4. What percentage of all women licensed are of a given age?

5. What percentage of all men licensed are of a given age?

6. What percentage of women at a given age are licensed drivers?

7. What percentage of men at a given age are licensed drivers?

The following table was designed to answer questions 1, 2, 3, 6 and 7. The answers to questions 4 and 5 are not available in this table.

The answers to these questions are not as simple as one might think at first conjecture. It requires very careful analysis of names in the files, percentages of the population, etc. All these things have to be taken into account when calculating the various parameters.

By a study of 14,967 cases taken from the files of the State of Iowa the following figures have been compiled to answer specifically the questions to numbers 1, 2, 3, 6 and 7. The ratio of licensees was nearly 26.6 per cent women and about 73.5 per cent men.

Table 1 contains the fundamental data necessary to put accident frequencies into meaningful form. At times trends are real, even though statistical evaluations at any one point along the curve may not show a significant difference. Experimental or sampling errors may account for occasional deviations which, on first consideration, seem out of line, and thus false conclusions regarding trends may be drawn.

Comparison may be made from this table at any age up to 60, then by five-year intervals up to the age of 90. The number of drivers in a given age group in Iowa may be closely estimated by sex, also the percentage at each age level that are licensed, and the percentage of all licenses in the state held by any age group. The stated annual mileage as obtained from a poll of the sampling drawn is given by the mileage index. This indicates the nearest number in hundreds of miles.

From such a table it is possible to group ages in any fashion desired and fairly reliable estimates may be made from the results. Unless the basic constants are approximately known, no valid conclusions can be drawn from accident figures.

Another source of error commonly found is anachronism. A certain group may be studied along with others of different ages. One individual may be noted for his accident record. It may be found that he has had six accidents. No account is made of when he had them, at what age or over what period of time.

Our first hypothesis set up for testing may be considered at this time. Since temporal distribution of reporting varies, what may be expected of spatial reporting? Within a state, is reporting quite uniformly carried out throughout the different districts, counties and population areas? A statistical evaluation of approximately equal population groups in Iowa combined according to population are presented in Table 2.

Table 1
PER CENT OF LICENSEES IN IOWA BY AGE AND SEX

Age	A Men	B Per cent of men licensed	C* Mileage Index	D Women	E Per cent of women licensed	F* Mileage Index	G Both Sexes
14	.02018	....	..	.....	....	..	.02018
15	.18161	7.7	32	.03363	0.9	10	.21524
16	.68608	20.0	42	.22197	3.8	14	.90805
17	1.63449	60.9	58	.43721	11.7	16	2.07170
18	1.85646	67.0	73	.78698	25.8	18	2.64344
19	1.66812	63.5	89	.56501	18.2	20	2.23313
20	1.47978	54.9	99	.56501	17.4	22	2.04479
21	1.58741	56.1	105	.58519	15.7	23	2.17260
22	1.62104	48.2	114	.68608	26.1	25	2.30712
23	1.86319	68.6	121	.71299	15.1	27	2.57618
24	1.95063	76.9	127	.58519	17.0	28	2.53582
25	1.93045	67.8	124	.77353	24.8	29	2.70398
26	1.91027	69.0	131	.71299	23.5	30	2.62326
27	1.87664	68.7	138	.76680	30.8	31	2.64344
28	1.96408	71.6	136	.76007	29.6	31	2.72415
29	1.71521	61.2	130	.76007	21.7	32	2.47528
30	2.08516	72.2	129	.70626	22.5	33	2.79142
31	1.82283	67.5	126	.57846	23.5	33	2.40129
32	1.79592	67.7	123	.56501	19.4	34	2.36093
33	1.66140	66.4	121	.63227	20.9	34	2.29367
34	1.58741	67.5	118	.55156	19.7	35	2.13897
35	1.49997	55.7	116	.62555	19.4	36	2.12552
36	1.49324	55.4	114	.58519	23.6	37	2.07843
37	1.48651	66.9	112	.68608	28.7	37	2.17259
38	1.46633	60.2	111	.71971	27.9	39	2.18604
39	1.31163	57.7	112	.62555	25.6	40	1.93718
40	1.49997	54.1	109	.62555	28.5	41	2.12552
41	1.17710	67.2	109	.73317	42.9	41	1.91027
42	1.33181	57.4	108	.58519	20.4	43	1.91700
43	1.17710	62.7	108	.51793	25.0	44	1.69503
44	1.10984	60.0	108	.48429	26.0	46	1.59413
45	1.18383	54.4	108	.57846	24.6	47	1.76229
46	1.17038	60.3	108	.48429	19.2	48	1.65467
47	1.21074	68.6	108	.54483	23.9	49	1.75557
48	1.22419	65.2	109	.42376	21.8	50	1.64795
49	1.19056	50.7	109	.53138	25.4	50	1.72194
50	1.18383	55.7	108	.46412	26.4	50	1.64795
51	1.00895	63.6	108	.41030	27.4	50	1.41925
52	1.02240	52.4	109	.36995	21.8	50	1.39235
53	1.10311	64.5	107	.53138	31.5	49	1.63449
54	1.09639	79.4	106	.46412	37.0	47	1.56051
55	1.06276	60.1	105	.41703	23.4	46	1.47979
56	.92823	62.8	104	.28250	20.5	43	1.21073
57	.96186	77.5	102	.30941	24.6	40	1.27127
58	.87442	65.7	100	.20852	12.6	35	1.08294
59	.91478	65.3	96	.29596	21.2	32	1.21074
60	.83406	67.3	92	.28923	21.4	30	1.12329
61	.96859			.22197			1.19056
62	.72644			.13453			.86097
63	.64573			.20179			.84752
64	.78025			.14125			.92150
65	.76680	66.9	75	.13453	21.4	23	.90133
66	.63900			.08744			.72644
67	.55156			.14798			.69954
68	.59864			.10762			.70626
69	.43048			.12780			.55828
70	.43048	57.8	71	.06726	23.8	18	.49774
71	.43048			.03363			.46411
72	.36322			.06726			.43048
73	.39013			.04708			.43721
74	.29596			.05381			.34977
75	.26905	45.7	70	.04701	8.8	15	.31606
76	.20179			.03363			.23542
77	.28250			.03363			.31613
78	.26233			.01345			.27578
79	.19506			.02018			.21524
80	.12780	65.8	69	.01345	4.6	12	.14125
81	.10089			.02018			.12107
82	.13453			.01345			.14798
83	.12107			.00673			.12780
84	.06054			.00673			.06727
85+	.25560	71.4	55	.....	....	..	.25560
Totals—	73.45			26.56			100.01

+Mileage index to two places in hundreds of miles. 1=100

Table 2

DISTRIBUTION OF ACCIDENTS ACCORDING TO DENSITY OF POPULATION

Group		Number of Counties	Accidents Actual	Accidents Expected	X^2
I	Dense	1	220	111.5	70.336[b]
II		2	124	102.9	4.317[a]
III		3	140	133.2	.342
IV		5	126	127.5	.018
V		5	94	98.3	.190
VI		8	83	105.8	4.938[a]
VII		10	96	109.0	1.557
VIII		10	88	100.2	1.484
IX		11	106	98.0	.646
X		12	73	95.8	5.423[b]
XI		15	88	116.7	7.057[b]
XII	Sparse	17	77	95.9	3.736

Component a—Significant at the 5 per cent level for one degree of freedom.

Component b—Significant at the 1 per cent level for one degree of freedom.

The Roman numerals consist of counties grouped together to give approximately equal populations. These were theoretically equated as given in the "expected" columns. In general, the Roman-numbered groups average around 200,000 and it may be fairly easy to estimate the population of individual counties by dividing the number of counties into 200,000. Iowa has 99 counties which average around 1,000 sq. mi. in area each.

By studying the table it will be noted that discrepancies exist between expected values and observed values. The chi-square index is an evaluation of the significance of the discrepancies. A chi-square above 3.841 indicates a 5 per cent level of confidence between two groups or with one degree of freedom. Above 6.635 it shows a confidence level of 1 per cent. Higher values show correspondingly greater probabilities of significance where more degrees of freedom are involved by summing groups. The component may be considered a rough indicator of discrepancies. It is to be noted that densely populated areas show an excess of reported accidents while sparsely settled counties show a deficiency. No speculations as to the reasons for this will be made here.

Next it seemed advisable to consider fatalities occurring within these areas since it is generally considered that accidents and fatalities are correlated, although fatalities are much more reliably reported. Table 3 shows the results obtained from this analysis.

By such technique we may set up any hypotheses that appears reasonable and check for correspondence with observed values. It might have been more logical to have used fatalities as the criterion or basis of comparison, but the results would be very similar in either case. From it

Table 3

RELATION BETWEEN REPORTED ACCIDENTS AND FATALITIES BY AREAS USING ACCIDENTS AS THE CRITERION

Group		Number of Counties	Accidents Actual	Accidents Expected	X^2
I	Dense	1	150	344.59	109.885
II		2	138	203.40	21.028
III		3	217	232.83	1.076
IV		5	194	203.40	0.436
V		5	138	159.82	2.979
VI		8	182	136.59	13.168
VII		10	216	153.67	25.282
VIII		10	205	155.22	15.965
IX		11	175	180.09	0.144
X		12	206	127.28	48.687
XI		15	203	152.12	17.018
XII	Sparse	17	160	135.04	46.135
				Total chi square	301.803**

**Highly significant. The sparse areas have more accidents than expected usually.

Table 4

SIGNIFICANCE OF DIFFERENCES FOUND IN REPORTED ACCIDENTS AT VARIOUS AGE LEVELS —MEN. EQUATED FOR MILEAGE

Age	Accidents Actual	Accidents Expected	X^2
15-17	24	16.85	3.085
18-20	103	62.85	27.324[b]
21-23	117	72.74	28.988[b]
24-26	116	99.22	3.142
27-29	103	96.32	0.498
30-32	78	87.12	1.043
33-35	52	71.64	5.789[a]
36-38	64	66.86	0.131
39-41	50	58.13	1.205
42-44	48	55.06	0.956
45-47	46	55.12	1.595
48-50	37	49.44	3.289
51-53	33	45.01	3.352
54-56	29	46.03	6.589[b]
57-59	27	37.63	3.117
60 & over	98	104.97	0.468

Component a—Significant at the 5 per cent level for one degree of freedom.

Component b—Significant at the 1 per cent level for one degree of freedom.

we see that there is very little correspondence between the accident-reporting index and the fatality index of similar population groups with the geographical size of area varying. A further study of reasons for this observation is being made.

Table 4 shows the incidence of accidents at different age levels for men. It is quite obvious that the trouble spot here lies with ages 18 to 23 inclusive. Ways and means of dealing with this group of drivers must be evolved. This may very well change with the licensing of more younger drivers.

Such techniques may also be used to spot areas of poor enforcement, low accident-reporting indices, or other conditions affecting highway safety. They may be useful in diagnosing the conditions related to the incidence of accidents and fatalities. A great deal of valuable information on the causes of accidents by repeated comparisons could be gained. The method with some modification may be valuable in solving certain problems of traffic engineering.

The data were plotted on a mileage-corrected basis for all age groups of men and women. It must be remembered that the mileage characteristics will likely change from year to year and such data must be kept up to date to be useful.

Discussion

Table 1 shows the per cent of licenses at each age level and the per cent of each sex population of drivers by age groups from 15 to 60 and by five-year age groups.

When driving mileage is plotted men are shown to drive most at ages 25-27 with an index of around 13,000 miles a year. Women drive most at higher ages, from 50-55, with an index of about 5,000 miles a year. About the same proportions hold for the sexes on daylight and nighttime driving, although men do much more night driving than women. About 1/3 of men's driving is reported to be at night for most of the age groups. Only about 1/5 of women's driving is reported being done at night. Older people report very low mileage being driven at night.

General Summary and Conclusions

A study of 14,967 Iowa drivers sampled from the drivers license files was made to answer two fundamental questions: Are reported accidents equally distributed among the population, age and number of licensees? Are accidents distributed equally among licensed drivers when mileage is held constant? What percentage of drivers is found in each age group?

A number of secondary questions were posed, the answers to which may be summarized in the following conclusions subject to the nature and limitations of the study:

1. There is a preponderance of evidence that male drivers 30 and under contribute very heavily to the accident total. The differences from 18 to 23 are significantly larger.

2. Male drivers spend six years before a noticeable improvement in their reported accident record appears. Women improve their records from the beginning of their driving period for the first 17 years.

3. Women differ from men at various age levels with respect to accidents reported against them. They drive many fewer miles a year than men and hold only about 25 per cent of the licenses. They do about 10 per cent of the driving and have about 9 per cent of the accidents reported to the state. The chi-square test of all men's and women's reported accidents was not significant, being 1,818, with a slight advantage in favor of women.

4. There is considerable difference for equal population areas, graded from most-dense to least-dense populations, between reported accidents in these areas. There tends to be an excess of accidents reported in larger cities and deficiency of reporting in sparsely settled districts, counties and areas according to population groups.

5. The techniques used are suggested for spotting various other conditions and situations which may be related to highway accidents.

6. Both the primary and corollary hypotheses set up for testing are rejected and the results would suggest a careful analysis of accident conditions within a state be made and used as the basis for a systematic highway accident reduction program.

7. One of the most serious problems is that of youthful male drivers. Whether the answer is probational licenses, driver education, closer surveillance and stricter enforcement, governors on cars, or other means is beyond the realm of this investigation. It appears that something will need be done, since a reasonable estimate would indicate the reduction of at least 10 per cent in automobile fatalities by bringing accidents or men below 30 down to the average of other ages.

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Non-Collision Fatal Accidents:

HOW MANY CAN BE PREVENTED?

by Roger G. Stewart, Vern L. Hill and Edward J. Warmoth

Much current emphasis on prevention of serious automobile accidents and reduction of serious injuries concerns accidents between two or more motor vehicles. These accidents, however, are very frequently minor or less serious than fatal collisions. In certain areas of the United States, collisions which involve just one motor vehicle that leaves the roadway constitute a major problem in reducing traffic fatalities. According to recent statistics, the state of Oregon is one of these areas for which considerable information on non-collision (NC) accidents is availabie.

This study of NC accidents consists of two parts. Part I reports some recent statistics of NC accidents in terms of their frequency of occurrence, location of occurrence, and number of fatalities. Part II will present some psychological analysis of possible contributing causes of some of these accidents.

STATISTICS OF NC ACCIDENTS (PART I)

In Oregon, every driver involved in any motor vehicle accident of any kind is required to report this accident to the police authorities within a few hours of its occurrence (unless deceased, of course). Statistics of NC accidents compared with other accidents were obtained or derived from annual summaries of NC accidents and others in Oregon for a period of four years (1954-1957, inclusive). In using four years, rather than a single year, it was assumed that any special influence of one year (for example, very heavy winter snows) would not assume considerable significance. These statistics may be given as answers to five main questions which one may ask of NC accidents within any state. These questions follow:

1. How many NC accidents occur?

During these four years, the annual summaries showed a total of 255,743 accidents. Of these, 9,744 accidents, or 3.8 per cent, were NC accidents.

2. Where do NC accidents occur?

Of the 9,744 NC accidents, 7,474, or 76.7 per cent, occurred in rural areas of Oregon. In rural areas, 9.9 per cent of all accidents were NC accidents, compared with 3.8 per cent of all accidents on a statewide basis. NC accidents, therefore, have been predominantly rural collisions.

3. How many fatal accidents are NC?

Statewide, 341 of 1,480 fatal accidents, or 23.0 per cent, were NC accidents. In rural areas, 312 of 1,148 fatal accidents, or 27.2 per cent, were of this type. Thus, fatal accidents in rural areas, rather than in urban areas, seem more likely to be NC accidents.

4. How many NC accidents are fatal?

Statewide, 341 of 9,744 NC accidents were fatal, or 3.5 per cent of them. In rural areas, 312 of 7,474 NC accidents were fatal, which is 4.3 per cent. Thus, by a slight percentage difference, NC accidents in rural areas were more likely to involve one or more fatalities than NC accidents in general. In fact, only 1.3 per cent of the 2,270 NC accidents in cities involved a fatality.

For comparison, consider collisions which involved two or more motor vehicles. In rural areas, 385 of 54,179 accidents involved a fatality, which is .71 per cent. For rural NC accidents, 4.31 per cent involved a fatality. These two sets of figures mean that, in the rural areas of Oregon, NC accidents were about six ($4.31/.71 = 6.1$) times as likely to involve a fatality as a collision that involved two or more motor vehicles.

5. How many deaths result from NC accidents?

Statewide, 370 of 1,718 deaths, or 21.5 per cent, resulted from NC accidents. In rural areas, these figures were 340 of 1,372 or 24.8 per cent of all rural traffic deaths. Thus, in terms of all these statistics, NC accidents in Oregon seem more likely to occur in the rural areas than in cities, and to be much more serious in the rural areas when they occur.

Following some analysis of these and other statistics, some plans were made to compile and analyze a limited number of reported facts pertaining to possible contributing causes of a sample of rural NC fatal accidents in Oregon.

CONDITIONS ASSOCIATED WITH NC ACCIDENTS (PART II)

This paper, similar to other studies of accidents, was based on information contained in official accident reports. Whether reports of accidents contain information that is sufficiently complete and reliable for statistical purposes has often been questioned by authorities; for NC accidents, problems of obtaining adequate facts seem almost insurmountable. NC accidents, for example, often occur without witnesses and without tangible evidences of probable contributing factors. Reports of investigating officers may simply indicate that the "Vehicle failed to negotiate curve," or that the "Driver lost control of vehicle on straight, level highway; details unknown." In order to preserve the factual character of statistics obtained in this analysis, information on each NC accident was obtained from official monthly summaries of all fatal accidents in Oregon compiled by the Oregon State Highway Department shortly following the end of each month. Except for very late reports, these

summaries include all motor vehicle accidents within the state which have been classified as fatal accidents by date of compilation.

Of the basic facts contained in these summaries, the following will concern this study:

1. Date (month, year)
2. Street or highway (urban, rural)
3. Type of accident (head on, other motor vehicle collisions, non-collision, fixed object, pedestrian, miscellaneous)
4. Conditions of accident (straight vs. curved road, dry vs. wet surface, daylight vs. darkness)
5. Driver behavior or condition

The monthly summaries revealed that NC accidents as a group seemed to differ considerably from other accidents as shown in Table 1, which follows:

Table 1
Statistics of Rural Fatal Accidents in Oregon
1957-1958

Travel Condition	Type of Accident					
	Head on	Other Motor Vehicle Collisions	Non-Collision	Fixed Object	Pedestrian	Total
Straight Road	60	99	83	34	51	327
Curved Road	25	13	90	19	1	148
Dry Surface	39	81	131	40	35	326
Wet Surface	46	31	42	13	17	149
Daylight	56	66	71	23	22	238
Darkness	29	46	102	30	30	237
Total	85	112	173	53	52	475*
Percentage	18	24	36	11	11	100

*Total does not include 15 accidents in miscellaneous categories and 80 accidents without complete data for travel conditions.

Table 1 shows that NC accidents as considered in this study, when compared with other accidents, seem to occur more frequently under the following two conditions:

1. Curved rather than straight roads

Of 173 NC accidents in rural areas of Oregon during 1957-1958, 90 accidents, or about 52 per cent of them, occurred at some point along a curved section of highway. Considering all 475 fatal rural accidents, only 31 per cent occurred on curves. NC accidents occurred much more often on curves than any other major type of accident shown in Table 1. If one realizes that the total mileage of straight sections of highways probably exceeds that of curved sections, even in rural Oregon, then these percentages assume greater actual significance.

2. Darkness rather than daylight

Of the same 173 NC accidents, 102, or about 59 per cent, occurred during hours of twilight or darkness. It is interesting to see that exactly 50 per cent of all 475 accidents shown in Table 1 occurred during hours of darkness. Again, if one realizes that total vehicle mileage is probably much lower during night than during daylight hours, these figures mean that more than half of the NC accidents occurred under periods of reduced mileage.

Based on Table 1, wet surface conditions seemed to have no special relationship with NC accidents as one might hypothesize. Only head on collisions seemed to occur much more often on wet surfaces than other types of accidents and accidents in general.

In addition to the above findings, other statistics indicated that NC accidents seemed to be somewhat seasonal compared with other accidents. This finding, in the writer's knowledge, has not been revealed by published studies of accidents in other areas. For simple comparative purposes, the frequencies of fatal accidents were tabulated for NC accidents and for all other types of motor vehicle collisions (head on, rear end, angle, turning, sideswipe) by months for the total period of two years. Then, all 12 months were divided into two groups which were called winter months (January, February, March, October, November, December) and summer months (April, May, June, July, August, September).

Statistics revealed that NC accidents seemed to occur more often during summer months, while other types of motor vehicle collisions seemed to be more characteristic of winter months. During the group of summer months, 136 of 301 fatal accidents, or 45 per cent, were NC accidents, while 98, or 33 per cent, involved two or more other vehicles. For the winter months, there were only 82 NC accidents, or 31 per cent of the total, compared with 119, or 44 per cent, of 269 fatal accidents. The remaining 67 summer and 68 winter accidents of this total of 570 rural fatal accidents in Oregon were classified in other categories (for example, pedestrian accidents).

Concerning specific conditions and possible driving behaviors associated with NC accidents, the 173 NC accidents shown in Table 1 were used as a total sample of NC accidents on rural highways in Oregon for two years which involved one or more immediate deaths. These 173 accidents were classified with regard to the three pairs of travel conditions into the eight possible combinations of three conditions, each pair being dichotomous (for example, straight vs. curved road). The most frequently occurring set of conditions among the eight combinations was the following: Curved road, Wet surface, Darkness.

Of the 173 accidents, monthly summaries mentioned specific information on the driver of the vehicle in 85 instances, leaving 88 accidents without an adequate basis for possible inferences on the behavior of the driver. These 85 accidents were assigned to the following classes of driving behaviors and conditions:

1. Speed, including driving too fast for conditions
2. Passing or turning movement, including momentary sideswipe
3. Intoxication, including driving under the influence of intoxicating beverages
4. Sleep, including drowsiness
5. Mechanical failures
6. Weather conditions of sudden or unusual nature and miscellaneous causes

In a very few instances, the monthly summary mentioned two of the above categories (for example, "Excessive speed, left rear wheel came off"). How should this accident be classified? Either of these two factors, speed and mechanical failure, is often sufficient in itself to precipitate a serious accident of some type. For some specific instance, however, it is difficult to evaluate the relative importance of two or more contributing causes. For these few cases, each of the two factors was considered to be half responsible for the NC accident, and these accidents were classified in terms of halves under the two categories concerned. This classification plan, thus, permitted study of possible relationships between the conditions of the driver (including his car) and the physical environment or travel conditions in which his NC accident occurred. These results are shown in Table 2, which follows:

Table 2
Conditions and Driving Behaviors Associated With Rural Non-Collision Fatal Accidents in Oregon 1957-1958

Travel Condition	Driving Behavior and Condition						
*R S L	Speed	Passing, Turning	Drinking	Sleep	Mechanical Failure	Weather, Miscellaneous	Total
S—D—L	2½	3½	½	2	2	3½	14
S—D—D	2½	4	5½	3	1	2	18
S—W—L	1½	5			1	½	8
S—W—D	½		1		½	6	8
C—D—L	3½		2½			5	11
C—D—D	9½		3	2	1	4½	20
C—W—L							
C—W—D	1		1	1		3	6
Total	21	12½	13½	8	5½	24½	85
Percentage	25	15	16	9	6	29	100

*The three basic travel conditions have been indicated as follows: ROAD (R) as Straight (S) or Curved (C), SURFACE (S) as Dry (D) or Wet (W), and LIGHT conditions as Light (L) or Darkness (D).

The figures shown in Table 2 will be more meaningful after those in certain rows and/or columns have been combined. For example, consider the following interpretable groups of findings:

1. Speed was mentioned in the equivalent of 21 of the 85 accidents. Fourteen of these 21 accidents occurred on curves. Speed also seemed more crucial on dry surfaces and during darkness.

Passing or turning movements were mentioned in 15 per cent of the 85 accidents. All these accidents occurred on straight roads.

2. Drinking or intoxication was mentioned in 16 per cent of the 85 accidents. Most of these accidents occurred on dry surfaces and, as one might suppose, during hours of darkness.

Sleep or drowsiness was mentioned in only 8 of the 85 accidents, or 9 per cent of them.

3. Mechanical failures were mentioned in only 6 per cent of the 85 accidents.

The weather and miscellaneous causes were mentioned in 29 per cent of these 85 accidents. Among miscellaneous causes were included items similar to the following: "Child falls from vehicle on wide, sweeping curve"; "Driver swerves to avoid falling rocks."

From these three groups of findings, one might conclude that the following contributing causes underlie rural NC fatal accidents:

Improper Driving Behaviors

Speed (25 per cent), Passing or turning movements (15 per cent), or total of 40 per cent.

Improper Driving Conditions

Drinking or intoxication (16 per cent), Sleep or drowsiness (9 per cent), or total of 25 per cent.

Unusual Physical or Environmental Occurrences

Mechanical failures (6 per cent), Weather and miscellaneous causes (29 per cent), or total of 35 per cent.

Based on these findings, one might conclude that about 65 per cent (55) of these 85 fatal accidents were the direct result of specific driving behaviors (or lack of proper behaviors) and/or specific physical and physiological conditions which influence behavior. Concerning mechanical failures, the weather, and various other causes, some of these occurrences might actually have involved failure to cope with the onset of certain conditions. For example, how many drivers can cope with minor skidding on ice or during heavy snows? If one assumes that half of all these accidents would have been prevented by skillful maintenance and handling of the vehicle, then one might conclude that roughly 80 per cent of these 85 NC accidents were essentially preventable.

In conclusion, the results of this study indicate that NC accidents, like most accidents of other types, can usually be prevented by individual behavior *which is directed toward preventing them*. This behavior concerns innumerable situations. For example, the motorist who promptly corrects observable mechanical defects of his car exercises proper "preventive medicine" which may save his life sometime. The motorist who will not operate his car when he is not in proper physical and psychological condition also avoids considerable likelihood of serious difficulty. The motorist who operates his car in a manner consistent with basic principles of safe driving controls his driving safety to a considerable degree.

Most accidents, up to some point, could have been prevented, but beyond this point, under existing conditions, were inevitable. Few NC accidents can be prevented when one's car is beginning to leave the highway, but most skillful drivers will rarely if ever find themselves in this kind of emergency. Since basic principles of safe driving apply to motorists and driving conditions of all states, it would be interesting to discover whether NC fatal accidents in other states seem to be associated with these same underlying contributing causes. If so, additional studies would indicate further that NC accidents, like other motor vehicle accidents, are sufficiently preventable to mean that reasonable efforts to achieve this goal will be worthwhile.

ACCIDENT CHARACTERISTICS OF DRIVERS AT VARIOUS AGE LEVELS

by Elmer B. Siebrecht,
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Statement of the Problem

Highway safety has enjoyed a long period of promotion with a minimum of research. There is definite need for an evaluation program to pin-point the sources of troubles and to isolate the factors which are associated with motor vehicle mishaps.

Below the age of 30, accidents are the first cause of death to all persons living in the United States. Automobiles account for over one-third of the 100,000 accidental deaths in this country annually. About ten times as many persons are injured, maimed or crippled each year by accidents of all types and the *proportion* of such casualties due to motor vehicle accidents increases each year.

Research on this problem has been carried on at Iowa State College on various phases of driving behavior, highway safety and accident prevention since 1930. During the past five years a special study has been in progress to evaluate the effects of training on driving performance. After getting into the study it was found that so many variables were operating that any simple comparison of accident and non-accident groups could not be made without danger of spurious or biased results.

The present study is a comparison of two systematic samplings of drivers from the motor vehicle license files in Iowa. The first sampling was taken in 1950 and consisted of 7,692 cases of which 5,755 were men and 1,941 women. The second sampling was collected in 1953 and was made up of 7,334 cases.

For each of these total samplings additional data from that found in the State license files were obtained by a check sheet sent by first class mail to each individual in the samples. This included data on the method of learning to drive, mileage driven, educational level, marital status, type of car driven and certain information on other personal and driving habits. The total usable cases having complete data for the first sample was 1,419 which included 415 women and 1,004 men. The second sampling of 1,955 cases with complete data consisted of 542 women and 1,426 men. A chi-square of goodness of fit indicates that the respondents giving additional information are fairly representative of the total first sampling.

The present study represents a comparative review of the salient characteristics and relationships found of drivers from the groups upon which data were available. It may be considered as a progress report on a continuing study of characteristics of the driving population.

To crystallize the problem more succinctly the following working hypothesis was set up in the null form for experimental investigation: Men and women do not differ in driving habits and characteristics. Two corollary hypotheses may also be stated as follows: (1) Accidents are distributed equally among age groups, and (2) mileage is a satisfactory index of exposure for prognosticating accident involvement.

Results

Only the most salient findings can be stated in this paper which are as follows:

1. The proportion of women drivers is increasing in the population. In 1951 it was 1 in 4; in 1953 it was more nearly 1 in 3.

2. The proportion of younger drivers is also increasing in the population.

3. Violations and accidents are closely correlated and a

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record of violations gives a fair index of potential accident involvement.

4. Different types of moving violations are all associated with accidents to the same degree. The highest association is with speeding. Next is that of improper passing and third is failure to observe stop signs.

5. While the ratio of men and women drivers is changing, men still drive about 85 per cent or more of the annual mileage.

6. There is evidence of greater improvement in the driving records of men than in those of women although there is more chance for improvement in men's records. This may be a function of the accident reporting index.

7. About 1 woman in 9 has an accident record and only about 1 in 25 has a violation record.

8. About 1 man in 4 has an accident record and the same ratio holds for violations.

9. For women under 30 about 1 in 14 has an accident record while over 30 the proportion is 1 in 7 for having an accident record. This is partly because older women drive more miles a year.

10. For men under 30 about 6 out of 10 have accident records, while for men over 30 about 4½ out of 10 have accidents charged against them. The mileage driven is greater for younger men.

11. Annual mileage for all women on the average runs about one-third that for men of all ages.

12. Men have more years of experience than women in driving, particularly at the younger ages.

13. Among the variables studied the best single predictor of accident susceptibility for men is the number of violations the driver has recorded against him. The second is number of miles he drives at night. Next comes total annual mileage, age, miles driven from 12 a.m. to 6 a.m. and finally miles driven in daylight and years of experience in the order given. The relationships indicated are at the one per cent level of confidence of better.

14. For women the total prediction is higher with the following descending order of merit for variables used: miles driven at night, violations on the record, total annual mileage, and mileage driven during daylight. Older women and those with more experience have more accidents. Women's mileage peak comes later in life, around 50, than that for men which is around 26-27.

15. In general any meaningful comparison of the effects of training on driving efficiency will necessitate controls on at least each of the following variables: (a) age, (b) sex, (c) experience, (d) annual driving habits, (e) mileage driven at night, (f) mileage driven in daylight, (g) weather conditions, (h) the local accident reporting index along with other factors of selection which may introduce a bias in certain geographical areas.

Summary and Conclusions

It is quite clearly shown that the characteristics and habits of drivers of the two sexes, as well as those for the various age groups, vary greatly. Any method of comparison of results of training or other influences will need to be carefully controlled. So far as the original hypothesis is concerned, and within the frame-work, limitations, scope and methodology used in the present study, the following conclusions seem warranted:

1. The hypothesis that driving characteristics and habits of men and women are the same is rejected.

2. The first corollary hypothesis that accidents are distributed equally among the age groups is refuted. This fact is more marked for men than for women and is in the reverse direction, i.e., younger men have more accidents than older men while younger women have fewer accidents than older women.

3. The second corollary hypothesis, that mileage is a satisfactory index of accident susceptibility, is mildly sustained. Hours of the day in which driving is done is more important.

4. For men the best single indication of potential accident involvement is the number of violations recorded against the driver.

5. Since a close relationship was found between speeding violations and accidents, this figure should be an excellent indication of potential driving efficiency. At least apprehension for speeding too fast for conditions should be given considerable weight in any method used for prognosticating accident susceptibility, or in any evaluation system.

6. While mileage has not been entirely controlled in all instances throughout the study due to technical difficulties, the results herein given should have meaning from an actuarial point of view.

7. A new index of accident susceptibility is proposed to equate experience and mileage driven each year as given by the following formula:

$$\text{Index} = \frac{\text{Accidents}}{\frac{(\text{Years of driving} \times \text{annual mileage})}{100{,}000}}$$

By proper substitution it may be used for violations or for a combination of the two.

Further study is being made of the relationships herein described in order to secure a better criterion of driving efficiency. Any index based upon accidents or violations alone seems to be quite inadequate and somewhat unreliable.

Discussion

From Table 1 it is seen that the predictive index for men's accidents and violations is quite low. Variables 9, 10 and 11 could not be used since they introduce a spurious relationship to the criterion. All the other variables showed a significant relationship to the criterion except year of car, miles on car, and schooling or educational level. As would be expected, age correlates high with experience. Schooling correlates negatively with age, since younger men get more education on the average. There seems to be a low negative relationship between age and violations indicating older male drivers make fewer violations. Correlations with the A-V index are also slightly negative, but it is significant at the one per cent level. Lower age groups with less experience have higher A-V index. More miles on the car indicates more accidents.

It would be difficult to predict accidents and violations

from ony one of the variables used here with any strong certainty. In other words, the driver's history and driving will not give a highly reliable picture of his susceptibility to future accidents. There are numerous factors of the driving environment which influence the tendency to get into accidents. That some of these are most likely personality syndromes are shown by the marked relationship between violations and accidents.

The person with more violations, especially of a certain type, also has more accidents. Only men are considered here since women have relatively few violations, in fact, too few to make a comparison. For men the order of merit relationship was speeding, improper passing, and failure to stop for stop signs. Many categories showed few listings and hence were all thrown together. When all violations were considered together a highly significant association was also found. Thus one might well use the number of violations a male driver has as an instrument of selection for accident susceptibility.

When considering female drivers in Table 2 it is first noticeable that the total predictive index is much higher than for men, even when fewer variables are used. Not so many correlations are significant, partly because of the smaller numbers of cases. The individual r's are of about the same magnitude. If we were to pin-point some of the more substantial coefficients it would be miles driven in daylight, total miles, after midnight miles, and total miles driven. Thus it would seem that mileage is about the only factor we could use in predicting accidents and violations of women drivers. Violations would be less valuable for women than for men as a selection instrument of risks, partly because they are less frequent. Women rarely have over three accidents on their records while men run up to nine or more.

Table 1

Table of Intercorrelations and Validity Coefficients—1015 Men

Factor	1	2	3	4	5	6	7	8	9	10	11
1. Age	——										
2. Year of car	.069							R_y-145678=.187			
3. Miles on car	—.083	—.728									
4. Experience	.903	.125	—.067								
5. Day miles	.080	.170	—.014	.144							
6. Night miles	—.143	.126	—.011	—.067	.457						
7. Midnight miles	—.167	.044	.023	—.117	.242	.712					
8. Total miles	.018	.175	—.020	.091	.906	.725	.462				
9. Schooling	—.220	.142	—.072	—.218	.075	.050	.058	.062			
10. Violations	—.027	.010	—.011	.005	.103	.086	.076	.120	.032		
11. Accidents	—.125	.017	—.001	—.109	.075	.127	.101	.107	.002	.088	
Y—A-V Index	—.121**	.018	—.004	—.096**	.100**	.141**	.115**	.134**	.013	.398**	.923**

**Significant at the 1% level
A-V Index=(Number of accidents plus ½ number of violations 1948-49) × 10

Table 2

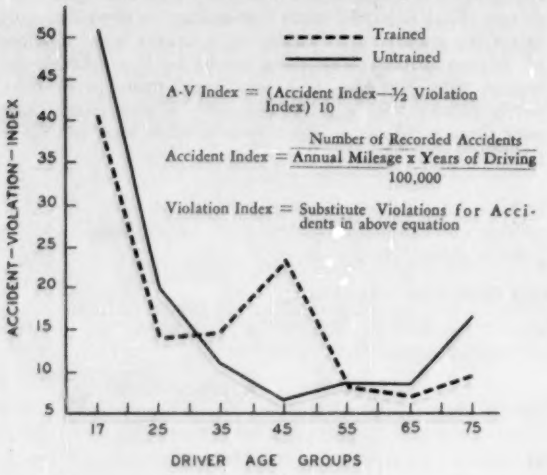
Table of Intercorrelations and Validity Coefficients—493 Women

	1	2	3	4	5	6	7	8	9	10	11
1. Age	——										
2. Year of car	—.008								R_y-5678=.241		
3. Miles on car	—.053	—.690									
4. Experience	.888**	.031	—.025								
5. Day miles	.182	.081	—.019	.184							
6. Night miles	.145	.056	.026	.134	.364						
7. Midnight miles	.012	.068	—.028	.005	.230	.517					
8. Total miles	.179	.079	—.007	.180	.578	.492	.293				
9. Schooling	—.117	.112	—.128	—.120	.089	.040	.017	.077			
10. Violations	.079	—.011	—.043	.113	.045	.095	—.025	.054	.062		
11. Accidents	.043	.065	—.031	.039	.124	.209	.167	.161	—.025	—.023	
Y—A-V Index	.059	.063	—.039	.060	.131	.225	.159	.170	—.012	.176	.980**

**Significant at the 1% level but spurious in the case of accidents vs. A-V.
A-V Index=(Number of accidents plus ½ number of violations 1948-49) × 10

In studying the graph training seems to benefit men to the age of 28. From 28 to 55 the effect seems to wear off, but drivers with training over 55 seem to derive benefit. It is probable the older group shown are made up of commercial drivers. It is also possible that the ratio of trained to untrained drivers is smaller between 28 and 55.

Age and Accident-Violation Susceptibility (Men)



From data not shown in the graph, trained women have about half the accidents that untrained women have, while trained men show about one-fourth less accidents than untrained men.

Table 3

Association between Frequency of Violations and Accidents of Speed Violators and Non-Speed Violators—Men

	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
Speed Violators	140	158	134.1827	4.228
Non-speed Violators	221	188	211.8173	2.678
	361	346	346.0000	
			Chi-square	6.906**

**Significant at 1% level.

Table 4

Association between Training and Accident Involvement of Most Serious Violation Offenders—Men

	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
Trained	11	11	17.8750	2.644
Untrained	29	54	47.1250	1.003
	40	65	65.0000	
			Chi-square	3.647

Table 5

Association between Frequency of Violations and Accidents of Drivers Charged with Violations—Men

Violation Frequency	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
1	251	195	229.445	5.171
2	70	86	63.991	7.570
3	40	49	36.564	4.230
	361	330	330.000	
			Chi-square	16.971**

**Significant at 1% level.

Table 6

Association between "Speed" Violation and Accident Involvement—Men

	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
Non-Violators	1065	360	519.7645	49.1082
Speed Violators	150	233	73.2355	348.5290
	1215	593	593.0000	
			Chi-square	397.6372**

**Significant at 1% level.

Table 7

Association between "Improper Passing" Violation and Accident Involvement—Men

	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
Non-Violators	1065	360	407.8125	5.6056
Improper Passing	71	75	27.1875	84.0841
	1136	435	435.0000	
			Chi-square	89.6898**

**Significant at 1% level.

Table 8

Association between "Failure to Stop for Stop Sign" and Accident Involvement—Men

	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
Non-Violators	1065	360	400.2916	4.0556
Stop-Sign Violators	95	76	35.7084	45.4631
	1160	436	436.0000	
			Chi-square	49.5187**

**Significant at 1% level.

Table 9

Association between "Other Violations" and Accident Involvement—Men

	Number	Accidents Actual	Accidents Expected	$(o-e)^2/e$
Non-Violators	1065	360	457.7156	20.8608
"Other Violation" Violators	117	148	50.2844	189.8867
	1182	508	508.0000	
			Chi-square	210.7476**

**Significant at 1% level.